PEMAQUID LAKES
(MAINE)
LAKES LAY MONITORING PROGRAM
1988-89

FRESHWATER BIOLOGY GROUP (FBG)
UNIVERSITY OF NEW HAMPSHIRE
DURHAM

BY

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EDITED BY

A.L. BAKER J.F. HANEY

NH LLMP

To obtain more information about the Lakes Lay Monitoring Program (LLMP) contact the LLMP Coordinator (J. Schloss) at (603) 862-3848, Dr. Baker at 862-3845 or Dr. Haney at 862-2106.

PREFACE

This report contains the findings of a water quality survey of lakes in the Pemaquid Watershed, Maine, conducted in the summers of 1988 and 1989 by the Freshwater Biology Group (FBG) of the University of New Hampshire and the Pemaquid Watershed Association.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of results as well as more detailed "Introduction" and "Results and Discussion" sections. The description of methods and materials used by the Lay Monitors and the Freshwater Biology Group has been included in an appendix. While it is common practice to exclude this type of section from a "general" writing such as this, it is our goal to provide program participants with a complete report which can stand on its own for comparison to past as well as future lake studies.

Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective. Other appendices contain various supporting materials including a glossary of terms commonly used in this and other reports on water quality. The more adventurous reader is referred to these last sections, as well as the materials cited in the references section, if there is interest in learning more about the dynamics of fresh water systems.

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ACKNOWLEDGEMENTS

1988 marked the first year of participation in the Lakes Lay Monitoring Program (LLMP) for the Pemaquid Watershed Association monitors. David White took on the formidable task of coordinating the multi-lake study and acting as the liaison to the FBG.

Pemaqid Lakes Volunteer Monitors 1988 and 1989:

NAME	LAKE MONITORED
Wilfred S. and Naomi Doyle	Pemaquid Pond
Peter Fischer-	Boyd Pond
Earl Follett-	Biscay Pond
Cynthia and Jack Haarhues-	Biscay Pond
Mark A. Hatch-	Paradise Pond
C. Jackson-	Boyd Pond
David Libby-	Duckpuddle Pond
Albert "Mac" Rogers-	McCurdy Pond
Kenneth Stewart-	Duckpuddle Pond
R. Terenzi-	Boyd Pond
David White -	Biscay, Duckpuddle, McCurdy, Paradise and Pemaquid Ponds

The Freshwater Biology Group (**FBG**) congratulates the monitors on the quality of their work, and the time and effort put forth. We encourage these and other interested members of the Association to continue monitoring during the 1990 season.

The Freshwater Biology Group is a not-for-profit research program co-supervised by Dr. Alan Baker and Dr. James Haney and coordinated by Jeffrey Schloss. Members of the **FBG** field and lab staff for 1988-89 included Beth Ferrari, Carmilla Girgus, Bonnie Bruce, Mary Tognetti, Martin Nackman, Barent Rice, Mara Calahan, Kathleen Mahoney and Elizabeth LaPointe.

The **FBG** acknowledges The College of Arts and Sciences Office of Academic Affairs for funding and furnishing laboratory and storage space. The UNH Office of Computer Services provided computer time and data storage allocations.

Participating groups in the **LLMP** for 1988 and 1989 included: The New Hampshire Audubon Society, Derry Conservation Commission, Nashua Regional Planning Commission, Center Harbor Bay Conservation Commission, Governor's Island Club Inc., Little Island Pond Rod and Gun Club, Walker's Pond Conservation Society, United Associations of Alton, the Pemaquid Watershed Study Group, the associations of Baboosic Lake, Beaver Lake, Berry Bay, Big Island Pond, Bow Lake Camp Owners, Lake Chocorua, Crystal Lake, Dublin Lake, Great East Lake, Goose Pond, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Mendum's Pond, Merrymeeting Lake, Mascoma Lake, Moultonbouro Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Perkins Pond, Pleasant Lake, Silver Lake (Harrisville), Silver Lake (Hollis), Silver Lake (Madison), Squam Lakes, Lake Sunapee, Sunset Lake, Swains Lake, Lake Winona, and Wentworth Lake and the towns of Alton, Amherst, Hollis, Madison, Merrimack, Strafford and Wolfeboro.

1988 NON-TECHNICAL SUMMARY

Weekly monitoring was undertaken at Duckpuddle, Pemaquid, Biscay, Paradise and McCurdy Ponds by the volunteer monitors.

1) Average water transparency at Pemaquid and McCurdy Ponds was high, the sign of a clear and less productive lake. The secchi disk was visible as far down as 6.5 and 6.7 meters respectively (about 22 feet). This indicates the deepwater sites on the lake are relatively low in dissolved color and suspended matter such as algae and particulates. Duckpuddle, Biscay, and Paradise Ponds had lower transparency averages in 1988 (3.1, 3.9 and 3.4 meters respectively) indicating a higher amount of algae and color as would be expected in shallow systems.

2) Chlorophyll *a* concentrations for the surface waters of Duckpuddle, Pemaquid, Biscay, Paradise and McCurdy Ponds were at moderate levels. Chlorophyll levels indicate the extent of algae growth in the water. Concentrations in the mixed layer of water averaged 3.7 milligrams per cubic meter (mg m-3, equivalent to about 3.7 parts chlorophyll per billion parts water) at Pemaquid, 5.2 at Duckpuddle, 2.8 at McCurdy, 3.0 at Biscay and 4.0 at Paradise. Generally, concentrations below 3 mg m-3 are common to less productive, clear lakes and values above 7 mg m-3 are common in productive lakes. Concentrations at Duckpuddle Pond did exceed 7 mg m-3 in mid-September indicating higher nutrient levels are available during the fall mixing of the lake.

3) Dissolved lakewater color levels for Duckpuddle and Paradise Ponds were high. Pemaquid and Biscay Ponds had moderate color and McCurdy Pond was low in dissolved color. Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality. Large amounts of dissolved color may occur naturally but also occur during deforestation and development within the watershed.

4) Total phosphorus (nutrient) levels were low at the outlet sites sampled. All samples were in the range of 3 to 12 parts per billion (ppb) phosphorus. A concentration of 15 parts per billion (ppb) is commonly thought of as the boundary between less productive and more productive lakes, and is usually enough to cause algal blooms. Increased phosphorus levels late in the summer suggests that some nutrient loading from cultural sources is occurring within the watersheds of Pemaquid and Biscay Ponds.

5) For all measurements considered and averaged for the season, McCurdy Pond would be classified as having low productivity, a clear, oligotrophic lake. Duckpuddle, Pemaquid, Biscay, and Paradise Ponds are more productive, mesotrophic systems. It is important to note that Duckpuddle did show signs of high productivity especially late in the season.

1989 NON-TECHNICAL SUMMARY

Weekly to biweekly monitoring was undertaken at Duckpuddle, Pemaquid, Biscay, Paradise, Boyd and McCurdy Ponds by the volunteer monitors.

1) Average water transparency at Biscay and McCurdy Ponds was high, the sign of a clear and less productive lake. The secchi disk was visible as far down as 6.5 (about 22 feet) and 5.6 meters respectively. This indicates the deepwater sites on the lake are relatively low in dissolved color and suspended matter such as algae and particulates. Duckpuddle Pond had the lowest transparency with the disk disappearing after 2.1 meters depth, the sign of a productive lake. Pemaquid and Boyd Ponds had moderate transparency averages in 1989 (4.7 and 4.5 meters respectively) indicating a higher amount of algae and color as would be expected in shallow systems. Average transparency decreased in 1989 from 1988 averages for all ponds except Biscay and Duckpuddle. Paradise Pond secchi readings consistently bottomed out due to a shallower sampling site or lower water levels in 1989 so no comparisons can be made.

2) Chlorophyll *a* concentrations for the surface waters of Duckpuddle, Pemaquid, Biscay, Paradise and McCurdy Ponds were at moderate levels. Chlorophyll levels indicate the extent of algae growth in the water. Concentrations in the mixed layer of water averaged 4.5 milligrams per cubic meter (mg m-3, equivalent to about 4.5 parts chlorophyll per billion parts water) at Pemaquid, 11.1 at Duckpuddle, 3.4 at McCurdy, 4.2 at Biscay, 4.3 at Boyd and 4.6 at Paradise. Generally, concentrations below 3 mg m-3 are common to less productive, clear lakes and values above 7 mg m-3 are common in productive lakes. Thus, the concentrations for most ponds were moderate. Concentrations at Duckpuddle Pond did exceed 7 mg m-3 in throughout the season and the average for 1989 was over twice that of 1988. This suggests nutrient loadings for this pond are increasing. The other ponds generally had slight increases in 1989 averages compared to the previous year. Biscay Pond had the second greatest increase in seasonal average.

3) Dissolved lakewater color levels for Duckpuddle and Paradise Ponds were again high. Pemaquid, Boyd and Biscay Ponds had moderate color and McCurdy Pond was low in dissolved color. This was similar to the results found in 1989. Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality. Large amounts of dissolved color may occur naturally but also occur during deforestation and development within the watershed.

4) Total phosphorus (nutrient) levels were low at the sites sampled. All samples were in the range of 1 to 12 parts per billion (ppb) phosphorus. A concentration of 15 parts per billion (ppb) is commonly thought of as the boundary between less productive and more productive lakes, and is usually enough to cause algal blooms. For Paradise and Pemaquid Ponds July samples contained the highest phosphorus levels. This might be an indication that more nutrient loading occurs when the majority of lake users are present.

5) For all measurements considered and averaged for the season, McCurdy Pond would be classified as having the lowest productivity, a clear, oligotrophic lake approaching mesotrophy. Boyd, Pemaquid, Biscay, and Paradise Ponds are more productive, mesotrophic systems. Duckpuddle was very productive in 1989 and would be classified as eutrophic a change from 1988 when indications of moderate production were present.

COMMENTS AND RECOMMENDATIONS

1) We recommend that each association, including the Pemaquid Watershed Association continue to develop their data base on lake water quality through continuation of the long term monitoring program. The data base will provide information on the short and long-term cyclic variability that occurs in the lake and eventually will enable more reliable predictions of water quality trends.

2) We recommend phosphorus testing to be done during early spring, during times of heavy use (ie: 4 July, Labor Day) and late in the season when septic systems have been put through a full seasons use. Deep sites as well as tributary samples should be included. In addition, we recommend a mid to late summer sample be taken below the thermocline for each lake as this will lend insight into the internal nutrient cycling occurring.

4) As the development of a metalimnetic population of algae is suspected, occasional chlorophyll samples (late summer) from the thermocline, using the Meyer Bottle is suggested to monitor this phenomenon.

5) Since the Maine lake monitors have a high level of experience, we invite them to participate in our preliminary investigation of the effect of boat traffic on lakes. All that would be required is sampling in the morning and then the same day late in the afternoon on a "quiet day" followed by the same sampling approach on a day of heavy boat traffic. A discount for sample processing will be offered to try to minimize costs of additional testing. Contact the LLMP coordinator for further information.

6) As a general addition to our Lakes Lay Monitoring Program, we recommend that each lake in the Program begin monitoring the condition of the fish taken from the lake. The "Fish Monitoring" will require at least one lay monitor to record the species, length and weight and collect a sample of fish scales for each fish examined. In most lakes this will involve periodic creel census of sport fishermen on the lake.

Length-to-weight ratios give a measure of the nutritional condition of the fish. Age analysis of the fish scales (to be done at UNH) will tell how old each fish is. Together, these variables can help to track changes in the condition of the fish populations in the lake, and, of course, the "health" of the lake.

INTRODUCTION

During the past decade the NH Lakes Lay Monitoring Program has grown from a university class project on Chocorua Lake to a comprehensive state-wide program with over 500 volunteer monitors and more than 75 lakes participating. Originally developed to establish a data-base for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide. Current projects include: use of volunteer generated data for non-point pollution studies using a geographic based information system (GIS) in conjunction with the NH Office of State Planning, intensive watershed monitoring for the development of lake nutrient budgets, investigations of water quality and indicator organisms (fish condition, and stream invertebrates), and ground-truthing for remote sensing studies. Key ingredients responsible for the success of the program include innovative funding and cost reduction, assurance of credibility of data, practical sampling protocols and the interest and motivation of our volunteer monitors.

Importance of Long-term Monitoring

A major goal of a monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication; increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern since New England receives large amounts of acid precipitation yet the lakes contain little mineral content to neutralize the pollution.

In order to detect significant water quality trends sampling must be done throughout the ice-free season. Monthly sampling of a lake during a single summer provides information only on some of the variation that occurs. Short-term differences may be due to variations in weather or lake activity, or other chance events. The resulting short-term fluctuations may be unrelated to the actual long-term trend.

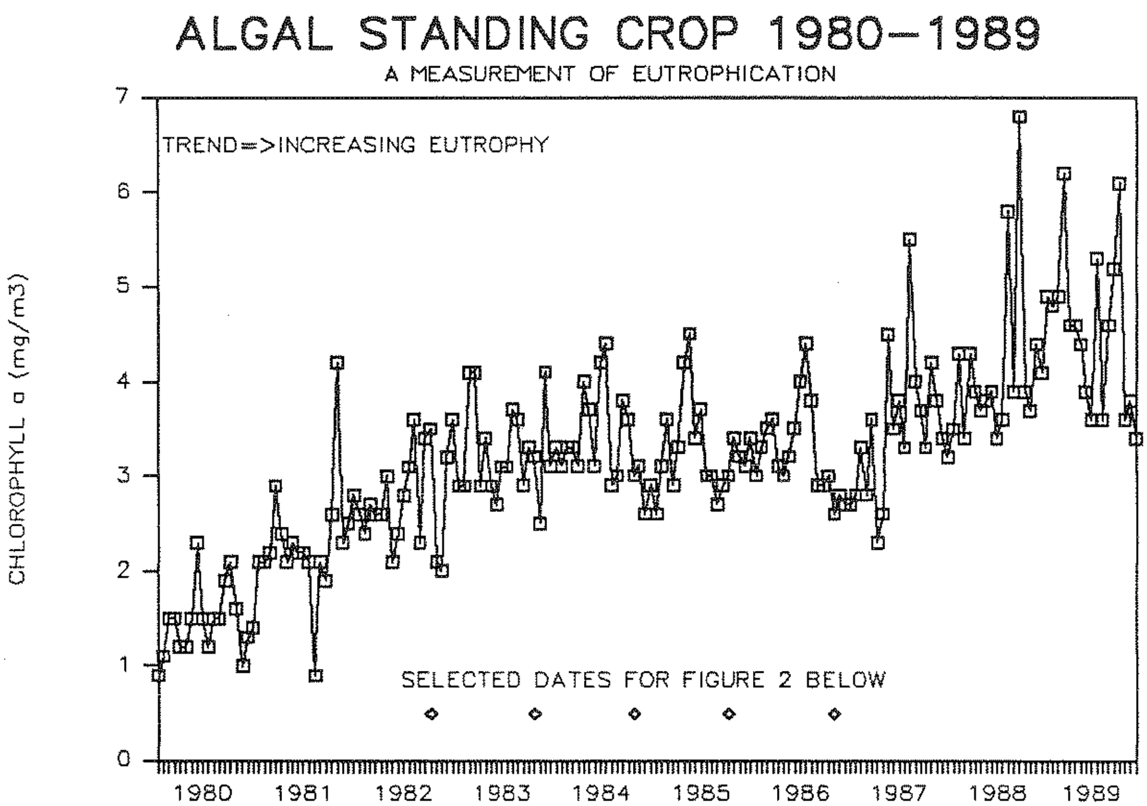


FIGURE 1- Weekly chlorophyll concentrations of a model lake measured during ice-free conditions. The long-term trend is that of increased eutrophication. Triangles represent late summer (August) dates sampled to create FIGURE 2 below.

Consider the hypothetical lake in Figure 1. Sampling only once a year during August from 1982 to 1981 would produce a plot (Fig. 2) suggesting a decrease in eutrophication. The actual long-term trend of the lake, increasing eutrophy, can only be clearly discerned by sampling additional times a year for a ten year period (Fig. 1).

Frequent monitoring carried out over the course of many summers can provide the information required to distinguish between short-term fluctuation ("noise") and long-term trends ("signal"). To that end, the lake must establish a long-term data base.

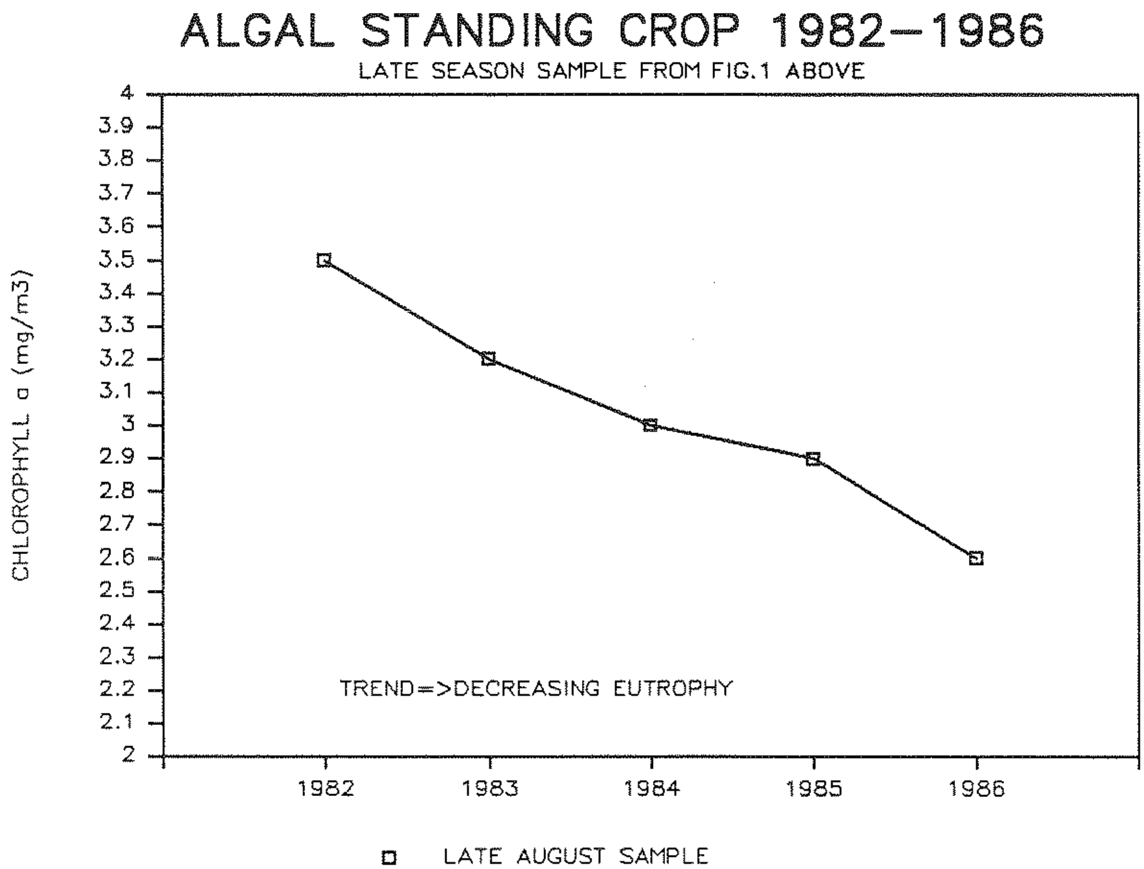


FIGURE 2- Late summer chlorophyll concentrations for the model lake in FIGURE 1. Note how limited sampling over five years suggests a different trend, that of decreasing eutrophy.

The number of seasons it takes to discern between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long term data base will indicate that the water quality of the lake has worsened, improved, or remained the same. As more data is collected prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of the lake.

There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose specific problems and corrective action can be initiated to handle the situation before it becomes more serious. Weekly monitoring by NH LLMP monitors has resulted in the detection of lake disturbances such as fertilizer run-off, sediment loading and faulty or inadequate septic systems. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a lay monitor. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it even may seem that one week's data is just the same as the next. Yet every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our lay monitors and are proud that their work is what makes the LLMP the most extensive, and we believe, the best volunteer program of its kind.

<u>Purpose and Scope of This Study</u>

This was the second year that monitoring of Biscay, Duckpuddle, McCurdy, Paradise, and Pemaquid Ponds was undertaken by the Freshwater Biology Group and the Pemaquid Watershed Association. In 1989 Boyd Pond was added to the program. Sampling emphasis was placed on a single open water site for each pond with nutrients samples taken at the outlets of selected ponds in the lake chain. The primary purpose of this report is to discuss results of the 1988-89 monitoring with emphasis on current conditions of the ponds including the extent of eutrophication.

RESULTS AND DISCUSSION OF LAY MONITOR DATA

Monitoring of each pond was done over an open water deep site. In 1988 and 1989 sampling for temperature, secchi disk depth, chlorophyll a, dissolved color, and total phosphorus took place on a weekly to biweekly basis. See Appendix A for the Lay Monitor data listing.

Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of secchi disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it. Secchi disk depths greater than 4 meters are typical of clear, less productive lakes. In 1989 values of water transparency at LLMP lakes were in the range 1.4 to 12.5 meters with a weighted average (average of lake averages) of 6.1 meters.

Average secchi disk transparency was 2.1, 3.0, 3.8, 4.7 5.2 and 5.6 meters for Duckpuddle, Paradise, Boyd, Pemaquid, Biscay and McCurdy respectively. Figure 3 compares all Maine sites studied in 1988 and 1989 to all of the lakes participating in the NH LLMP program. Average transparencies in 1989 were less (ie: the lakes were less clear) than 1988 averages at Duckpuddle, Paradise and Pemaquid Ponds. Biscay had greatly increased transparency and McCurdy had a slight increase in average secchi disk depth compared to last year. Lower transparency was generally due to both increases in chlorophyll and dissolved color (see Seasonal Trends section below).

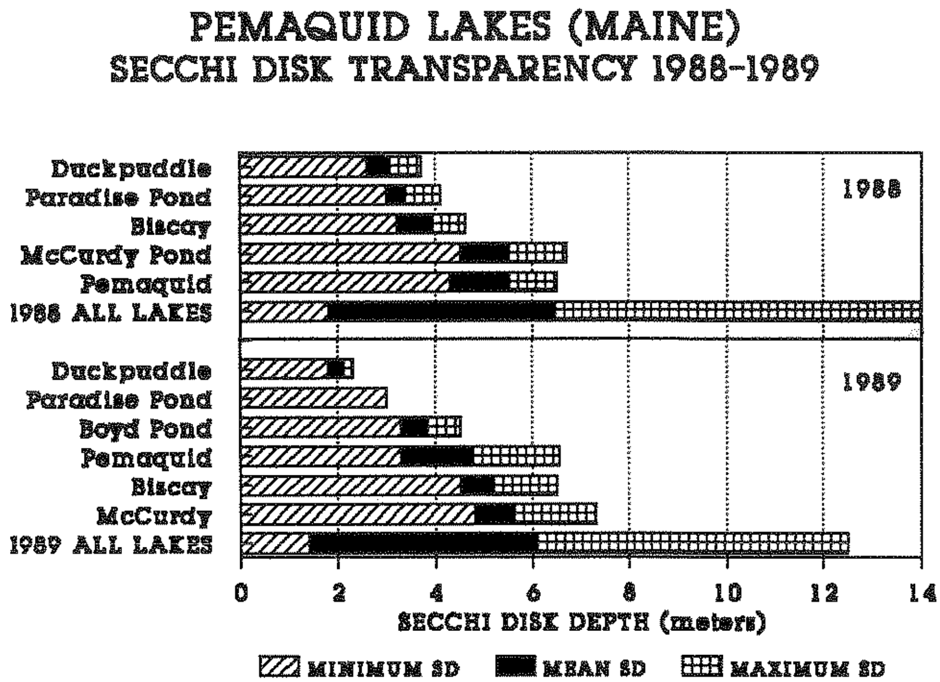


FIGURE 3- Comparison of transparency measurements between Pemaquid Lakes and the pooled NH LLMP data for years 1988 and 1989.

Chlorophyll a

The chlorophyll a concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Summer chlorophyll a concentrations average above 7 mg m-3 (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll a concentrations are generally less than 3 mg m-3. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll a generally between 3 mg m-3 and 7 mg m-3. In 1989 chlorophyll concentrations in LLMP lakes were in the range 0.1 to 25 mg m-3 with a weighted average (average of lake averages) of 2.8 mg m-3.

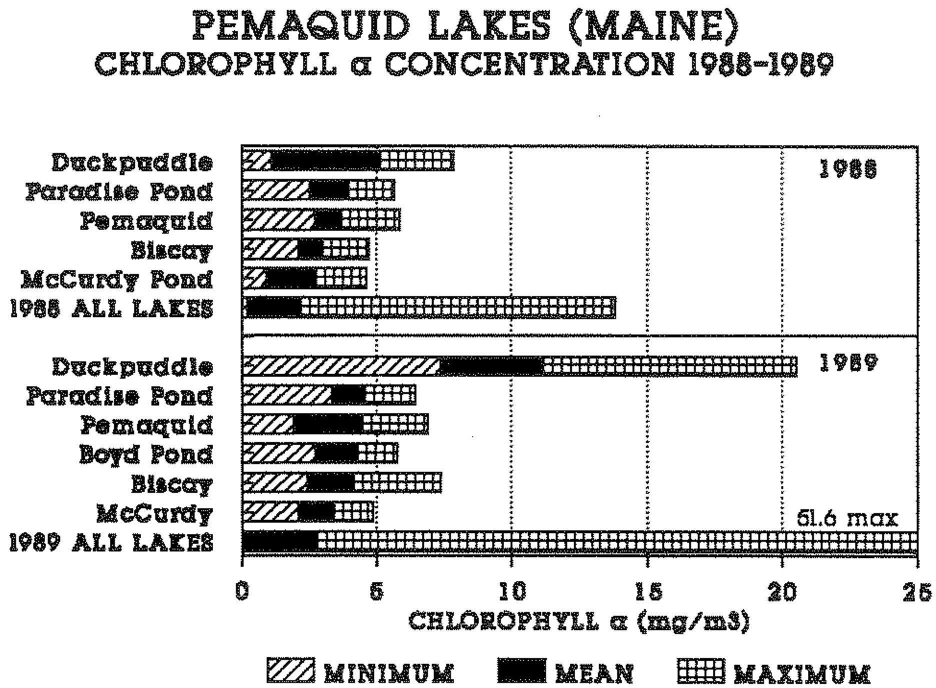


FIGURE 4- Comparison of chlorophyll a concentrations between Pemaquid Lakes and the pooled NH LLMP data for years 1988 and 1989.

Chlorophyll of the upper mixed water layer (epilimnion) was sampled at selected sites on most dates. Average chlorophyll concentrations were 3.4, 4.2, 4.3, 4.5, 4.6 and 11.1 mg m-3 for ponds McCurdy, Biscay, Boyd, Pemaquid, Paradise and Duckpuddle. Figure 4 displays a comparison of chlorophyll statistics between these ponds and other program lakes. Average chlorophyll a concentrations in 1989 were greater for all ponds compared to 1988 concentrations.

Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from humic substances, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Color is commonly expressed in units of a platinum-cobalt color standard (ptu). To put the color concentration in perspective, New Hampshire lakes studied in 1989 had a range of dissolved color from less than 1 ptu to 149 ptu with an average (all samples) of 25 ptu.

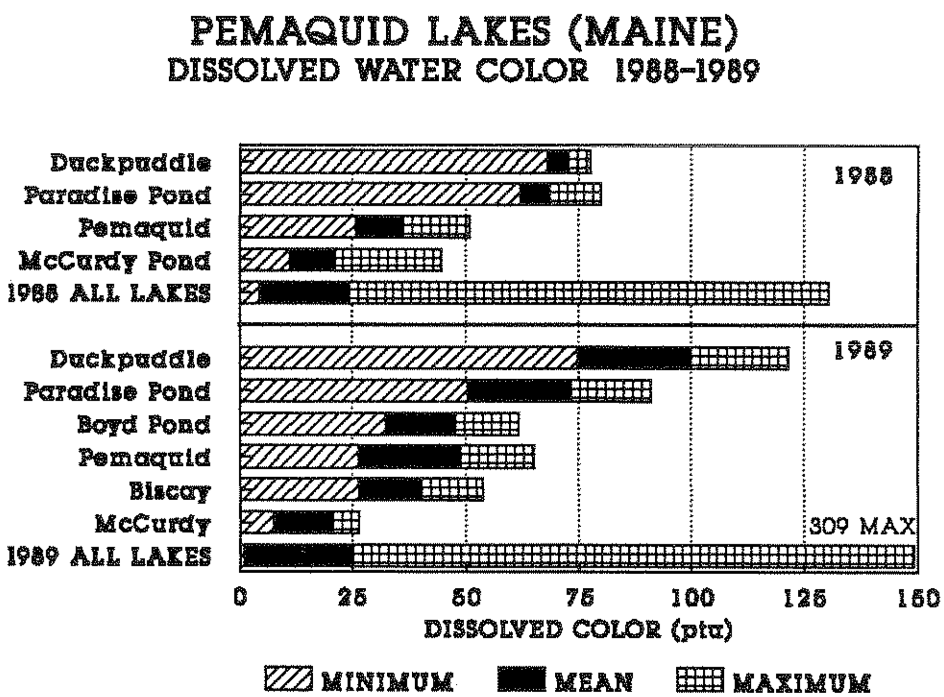


FIGURE 5- Comparison of dissolved organic color concentrations between Pemaquid Lakes and the pooled NH LLMP data for years 1988 and 1989.

Average dissolved color concentrations were 100, 73, 49, 48, 40 and 21 for Duckpuddle, Paradise, Pemaquid, Boyd, Biscay and McCurdy Ponds. All ponds except for McCurdy had either high or moderate color levels. Figure 5 offers a comparison of dissolved color means and ranges for each pond.

Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources include primarily anthropogenic activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton.

Total phosphorus samples were taken in May July and September (Table 1) at all six ponds. Depth integrated samples were generally low and, barring McCurdy Pond, were not indicative of the moderate to high trophic status of each pond. Higher July concentrations at Paradise and Pemaquid Ponds could suggest increased loading at the time of peak seasonal use of the lakes and houses within the watershed.

TABLE 1:
Pemaquid Lakes (Maine) Nutrient Samples:

Lake	Site	Date	Total Phos (ppb)
Biscay	2 Inlet	JUL-09-1988	2.6
Biscay	2 Inlet	AUG-24-1988	4.9
Biscay	2 Inlet	SEP-25-1988	11.7
Pemaquid	2 Inlet	JUL-16-1988	5.5
Pemaquid	2 Inlet	AUG-24-1988	5.3
Pemaquid	2 Inlet	SEP-24-1988	3.7
Biscay	1 North	MAY-09-1989	6.2
Biscay	1 North	JUL-16-1989	4.4
Biscay	1 North	SEP-16-1989	2.2
Boyd Pond	1 Center	MAY-09-1989	3.7
Boyd Pond	1 Center	JUL-15-1989	4.4
Boyd Pond	1 Center	SEP-16-1989	4.6
Duckpuddle	1 Deep	MAY-04-1989	5.7
Duckpuddle	1 Deep	JUL-16-1989	6.6
Duckpuddle	1 Deep	SEP-17-1989	7.9
McCurdy	1 Basin	MAY-09-1989	6.8
McCurdy	1 Basin	JUL-16-1989	0.9
McCurdy	1 Basin	SEP-16-1989	3.5
Paradise Pond	1 ReedIs.	MAY-09-1989	5.3
Paradise Pond	1 ReedIs.	JUL-16-1989	10.1
Paradise Pond	1 ReedIs.	SEP-18-1989	8.2
Pemaquid	1 Deep	MAY-09-1989	3.5
Pemaquid	1 Deep	JUL-15-1989	10.4
Pemaquid	1 Deep	SEP-17-1989	7.1

Seasonal Trends

Figures 6 through 16 contain the seasonal data of secchi disk transparency, chlorophyll and dissolved color concentrations for each of the ponds studied. The secchi disk is a useful tool to determine changes in lake water quality and is one of the more popular measurements used to communicate information to the general public. However, the causes for changes in lake transparency are not generally evident from the disk reading alone. Decreased transparency can be due to increases in algal biomass (measured as chlorophyll) due to increases in the nutrient loading from within the watershed. In this case the secchi disk is an indication of a man-made problem. On the other hand, an increase in dissolved color due to natural processes occurring within the watershed may also decrease water transparency. A third factor that can also affect transparency is sediment loading that results by poor soil conservation practices during construction, agriculture and even household activities The test for suspended sediment in water is generally cost prohibititive but sediment problems are usually indicated when a change in transparency occurs with no corresponding change to chlorophyll and or color.

For the Pemaquid Ponds, secchi disk depth corresponds well to chlorophyll and color changes, especially in the more productive ponds (Figures 6 through 16). During peak algal blooms, the secchi transparency decreases (for example see Pemaquid Pond; Figure 15). In 1988 (Figures 6,9,11,13,15) dissolved color in the highly colored lakes remained consistent throughout the season while the more moderate colored lakes had a decreasing trend. In 1989 color generally started out at high levels and then decreased as the season progressed (Figures 7,8,10,12,14 and 16).

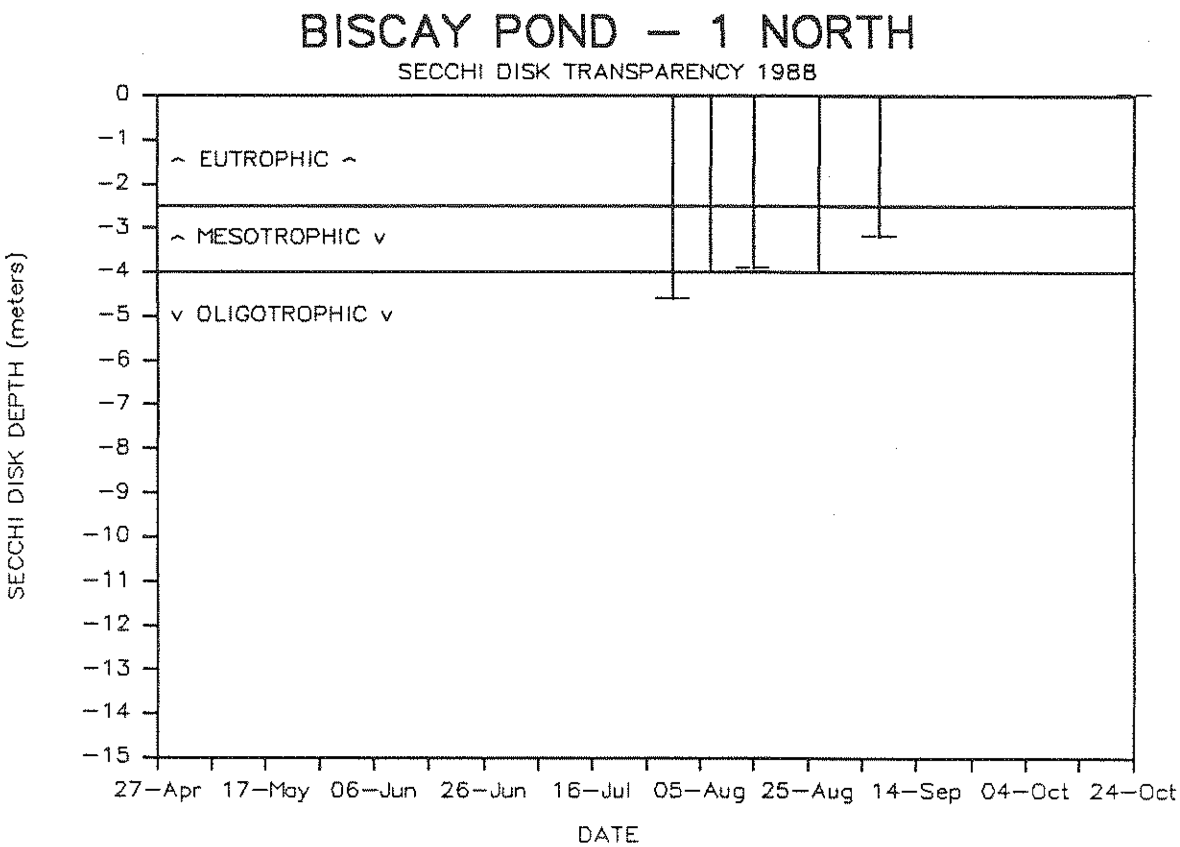
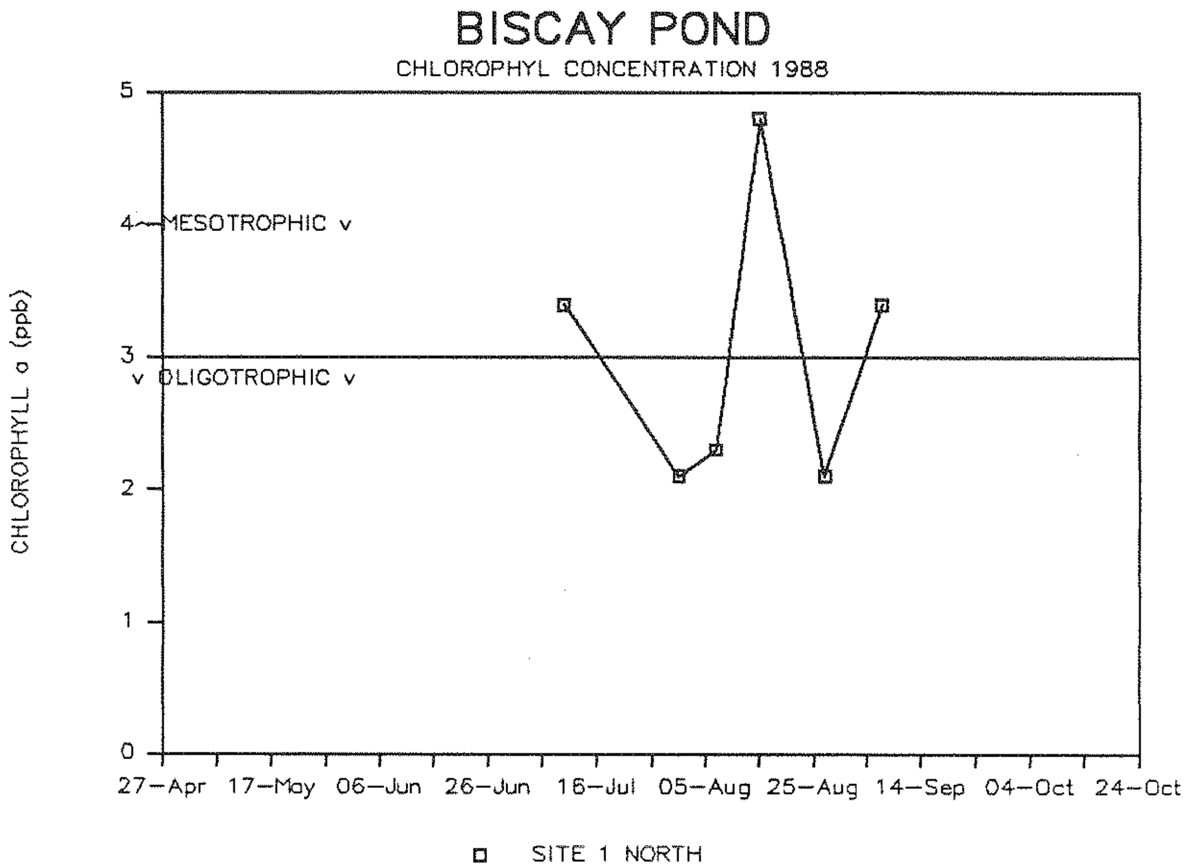
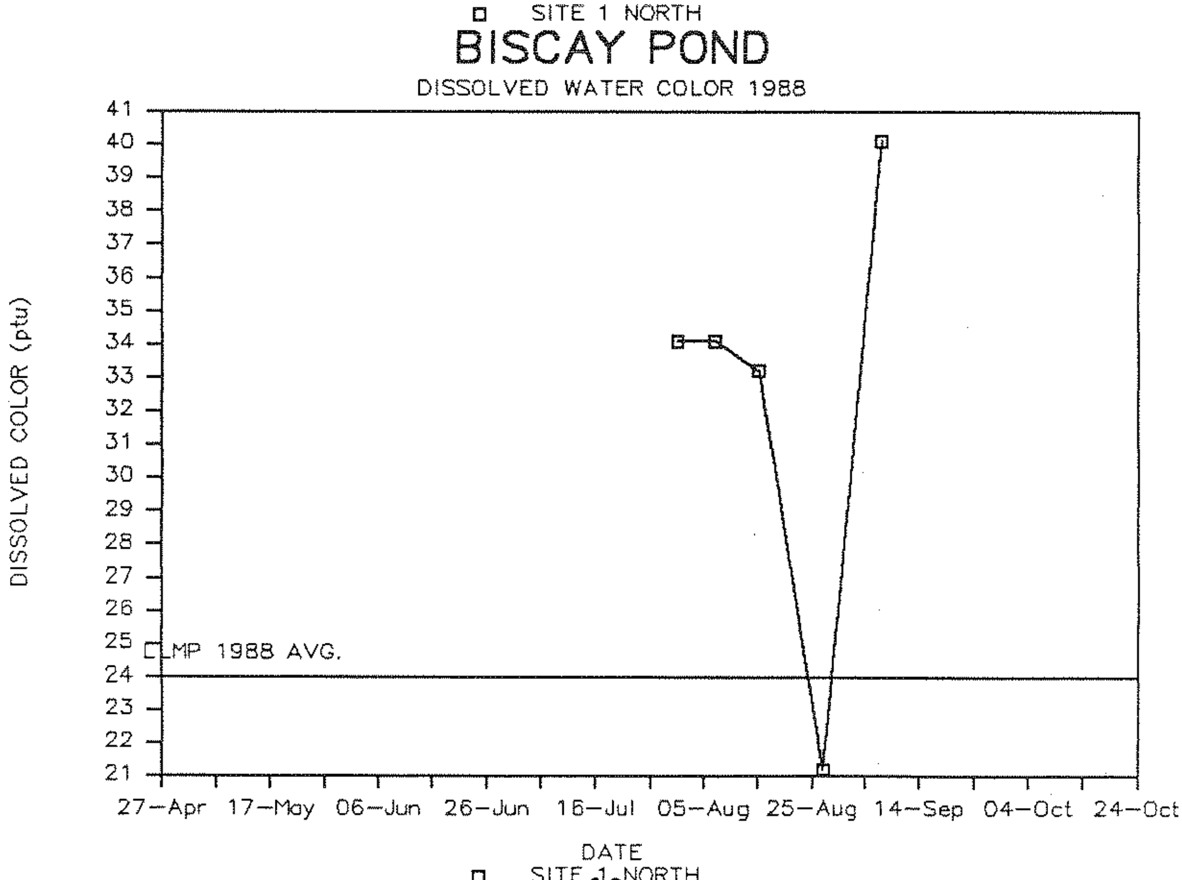


FIGURE 6- Seasonal trends in secchi disk transparency (above) Chlorophyll a concentration (top right) and dissolved color (bottom right) for Biscay Pond in 1988.


BISCAY POND
CHLOROPHYL CONCENTRATION 1988
CHLOROPHYLL a (ppb)
MESOTROPHIC v
v OLIGOTROPHIC v
0
1
2
3
4
5
27-Apr
17-May
06-Jun
26-Jun
16-Jul
05-Aug
25-Aug
14-Sep
04-Oct
24-Oct
SITE 1 NORTH


BISCAY POND
DISSOLVED WATER COLOR 1988
DISSOLVED COLOR (ptu)
CLMP 1988 AVG.
21
22
23
24
25
26
27
28
29
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31
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34
35
36
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38
39
40
41
27-Apr
17-May
06-Jun
26-Jun
16-Jul
05-Aug
25-Aug
14-Sep
04-Oct
24-Oct
DATE
SITE 1 NORTH

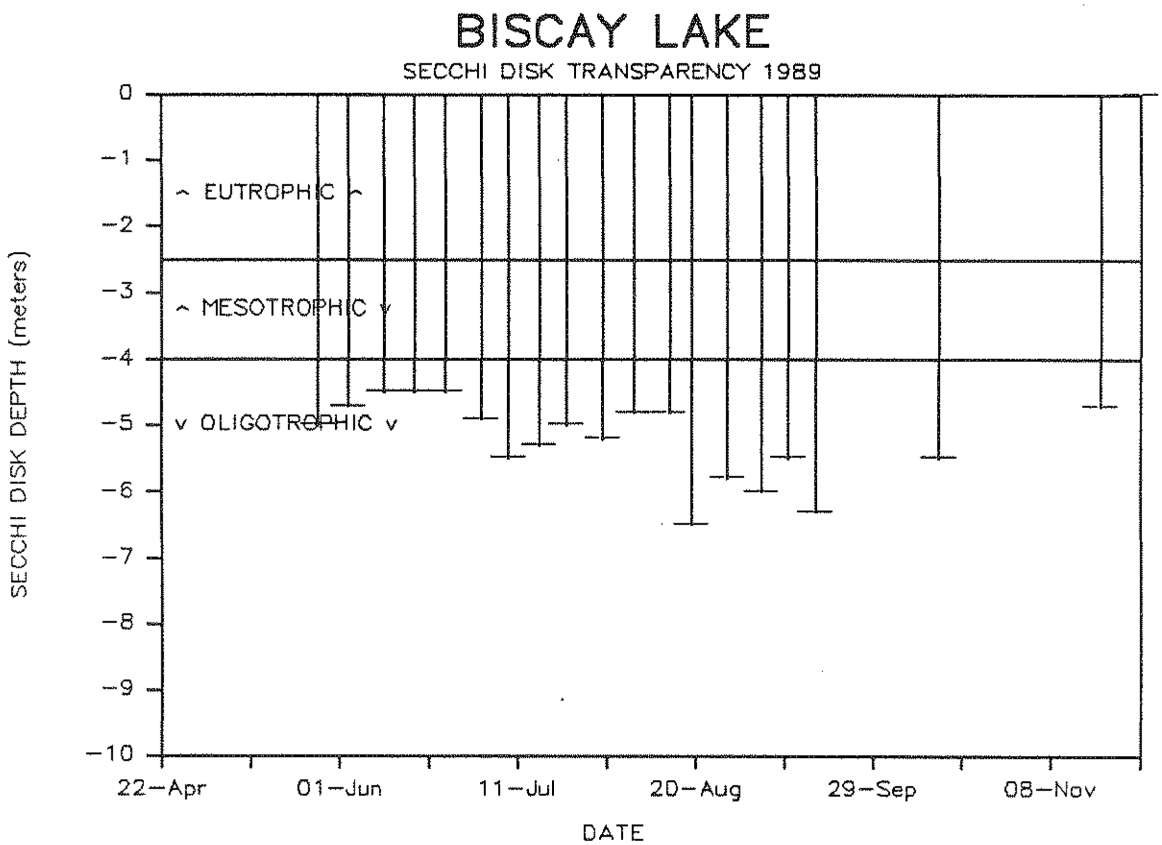
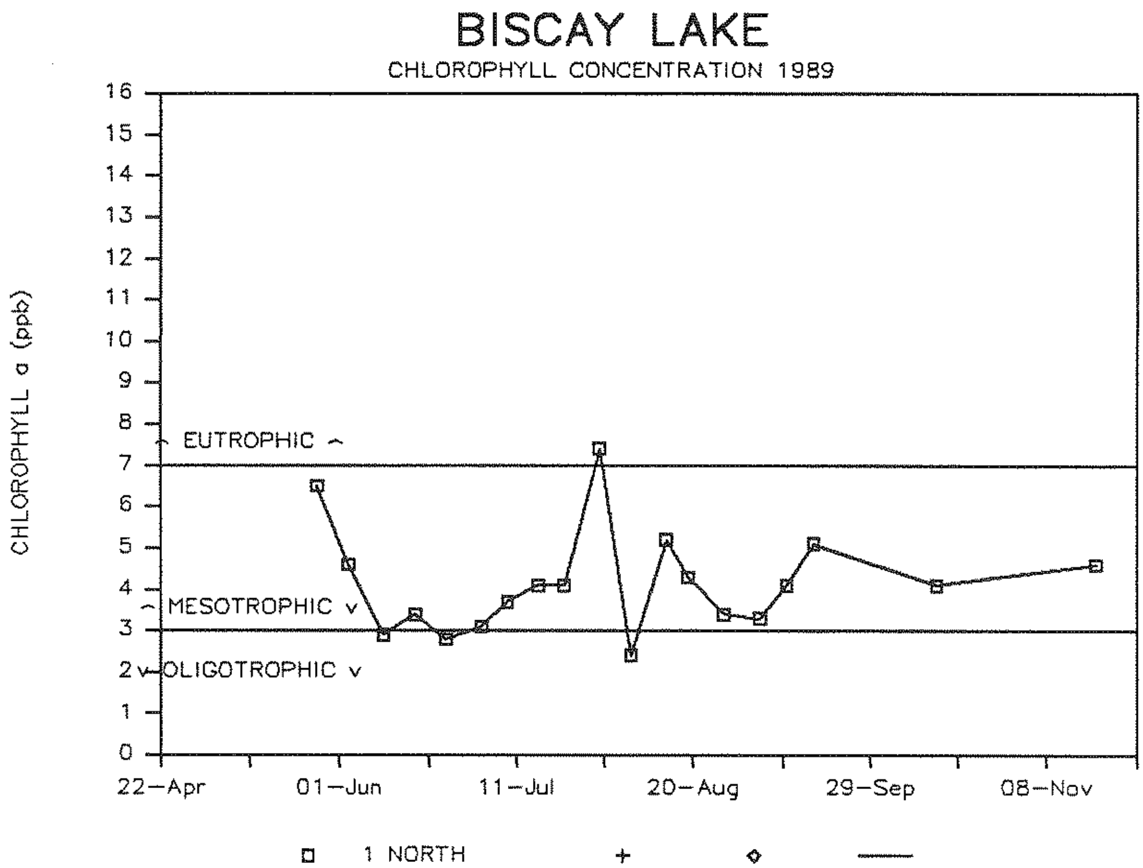
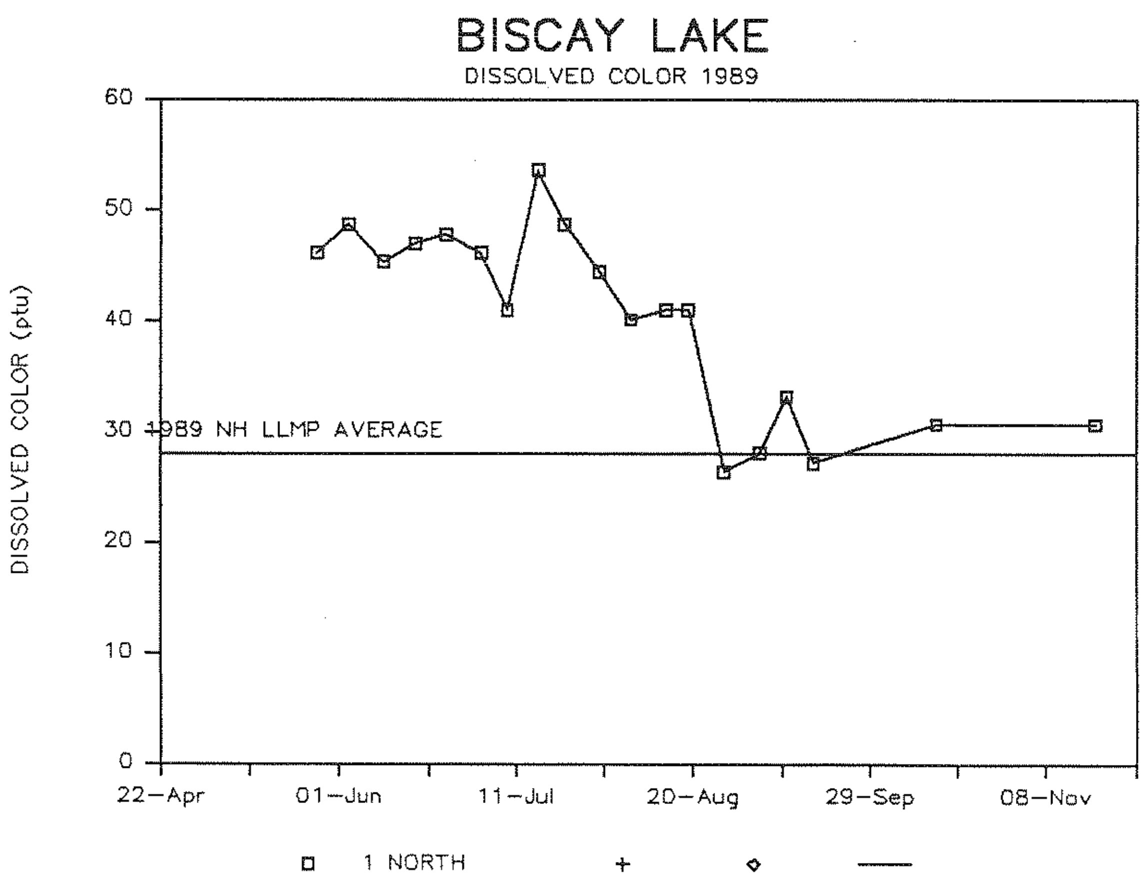


FIGURE 7- Seasonal trends in secchi disk transparency (above) Chlorophyll a concentration (top right) and dissolved color (bottom right) for Biscay Pond in 1989.


BISCAY LAKE
CHLOROPHYLL CONCENTRATION 1989
CHLOROPHYLL a (ppb)
EUTROPHIC
MESOTROPHIC
OLIGOTROPHIC
22–Apr
01–Jun
11–Jul
20–Aug
29–Sep
08–Nov
1 NORTH


BISCAY LAKE
DISSOLVED COLOR 1989
DISSOLVED COLOR (ptu)
1989 NH LLMP AVERAGE
22–Apr
01–Jun
11–Jul
20–Aug
29–Sep
08–Nov
1 NORTH

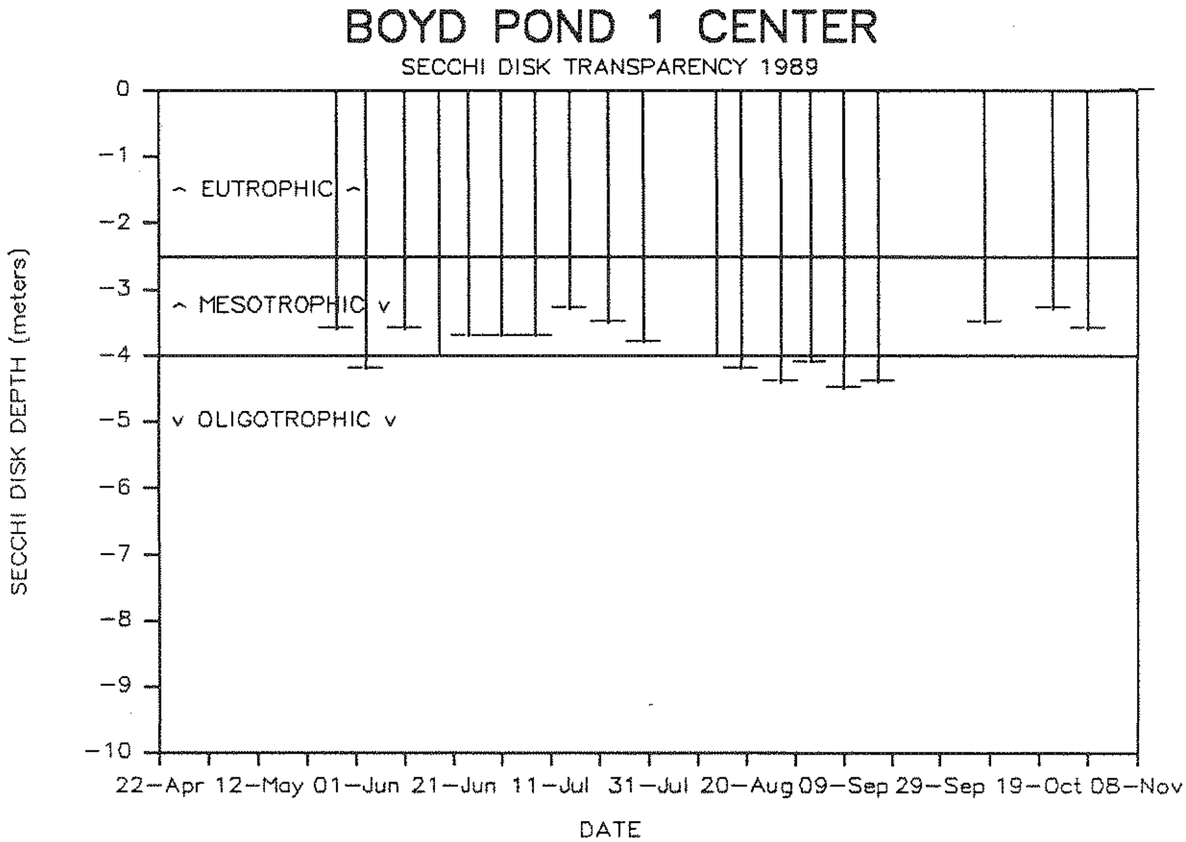
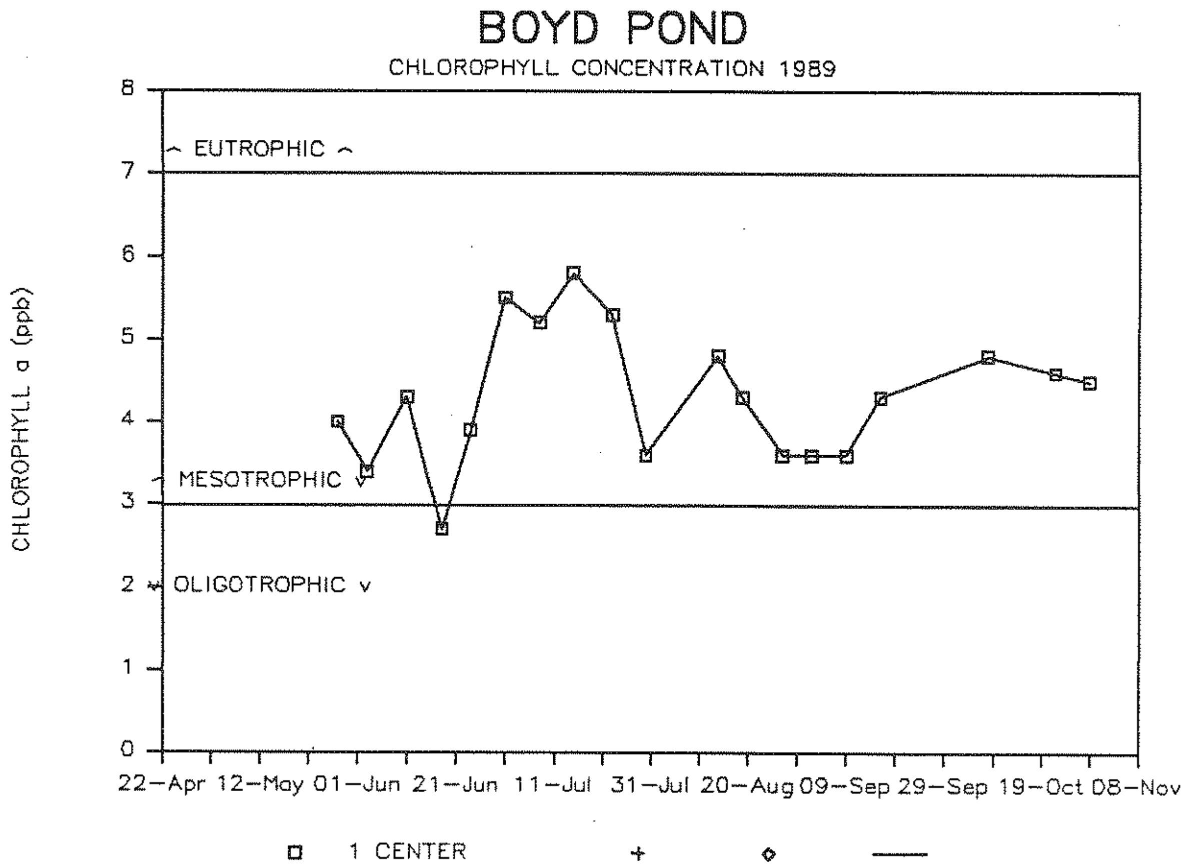
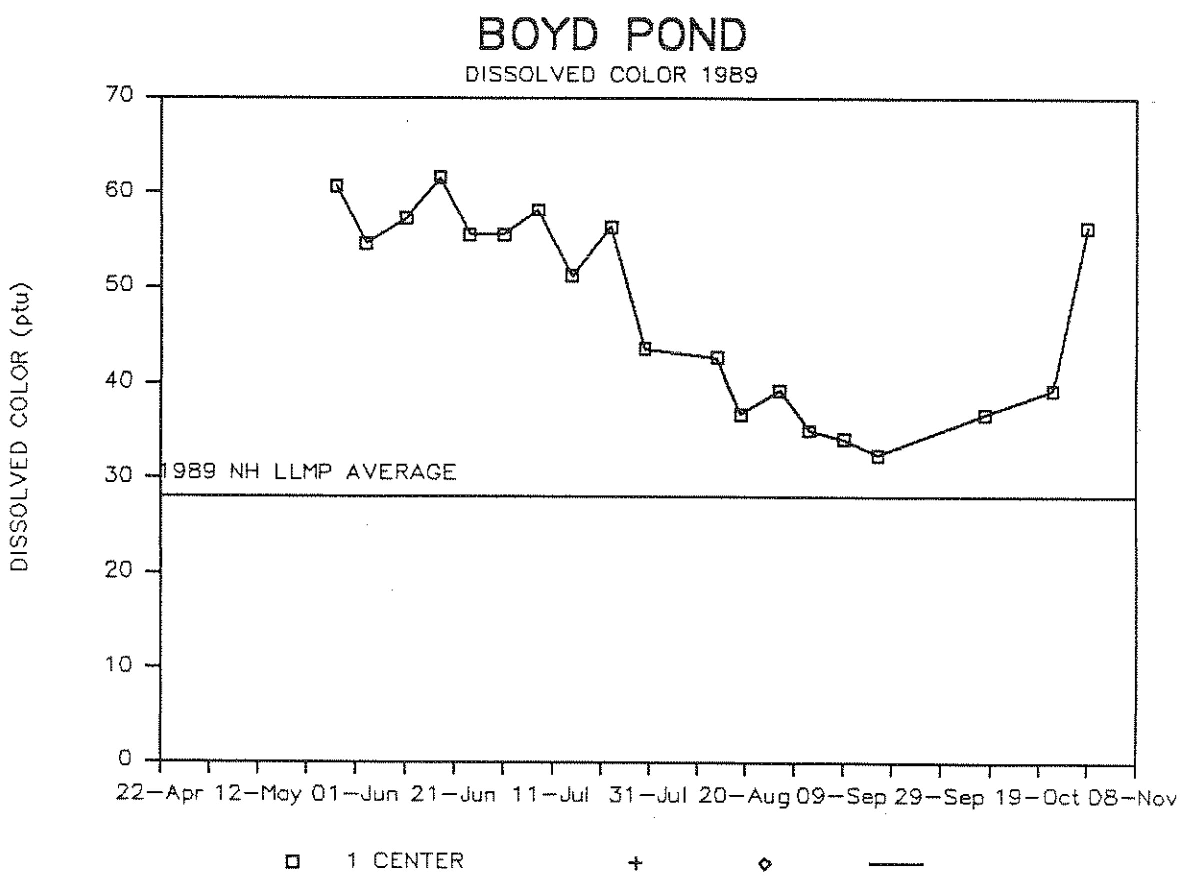


FIGURE 8- Seasonal trends in secchi disk transparency (above) Chlorophyll a concentration (top right) and dissolved color (bottom right) for Boyd Pond in 1989.


BOYD POND
CHLOROPHYLL CONCENTRATION 1989
CHLOROPHYLL a (ppb)
EUTROPHIC
MESOTROPHIC
OLIGOTROPHIC
0
1
2
3
4
5
6
7
8
22–Apr 12–May 01–Jun 21–Jun 11–Jul 31–Jul 20–Aug 09–Sep 29–Sep 19–Oct 08–Nov
1 CENTER


BOYD POND
DISSOLVED COLOR 1989
DISSOLVED COLOR (ptu)
1989 NH LLMP AVERAGE
0
10
20
30
40
50
60
70
22–Apr 12–May 01–Jun 21–Jun 11–Jul 31–Jul 20–Aug 09–Sep 29–Sep 19–Oct 08–Nov
1 CENTER

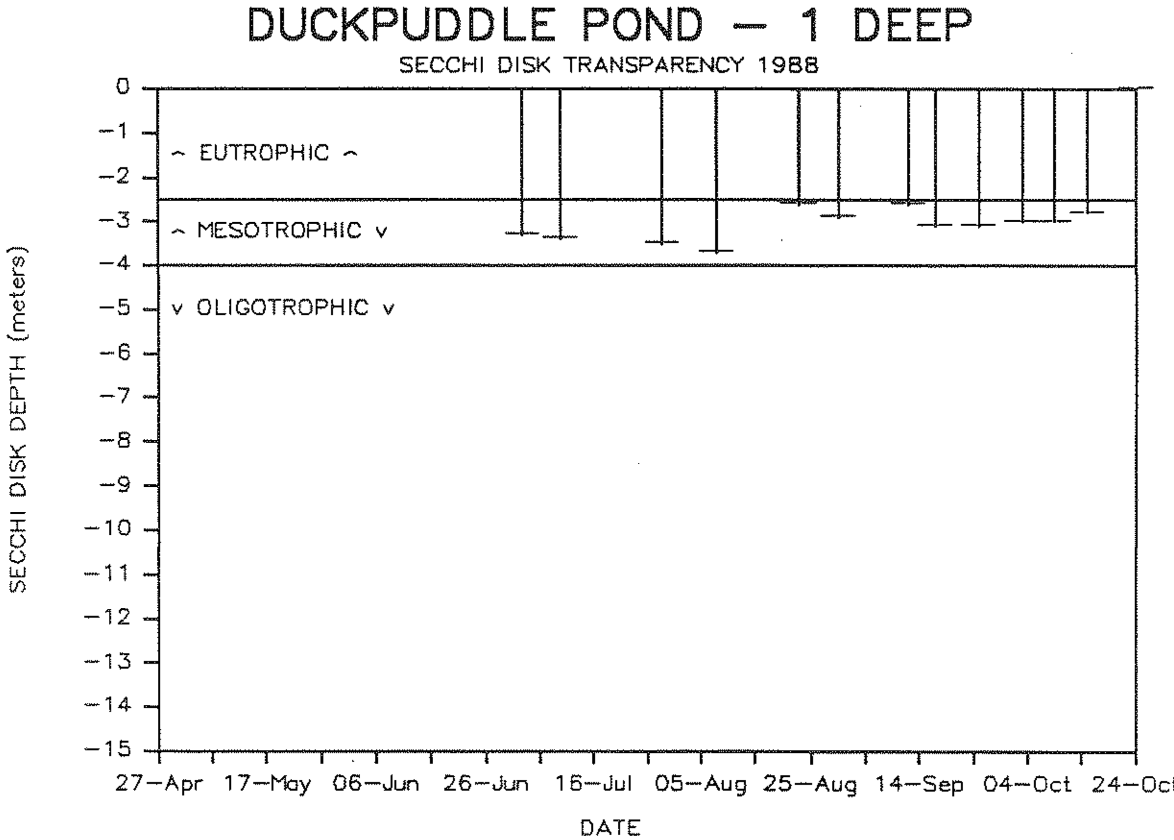
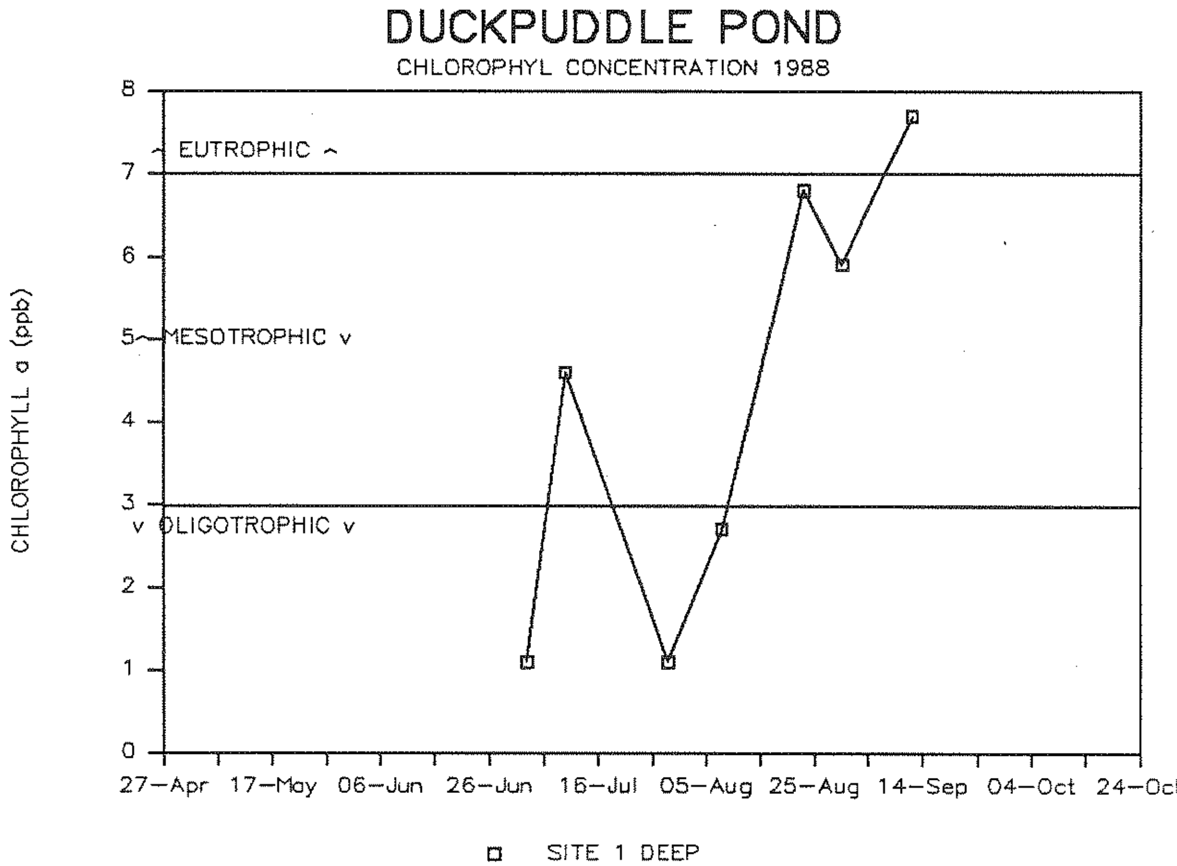
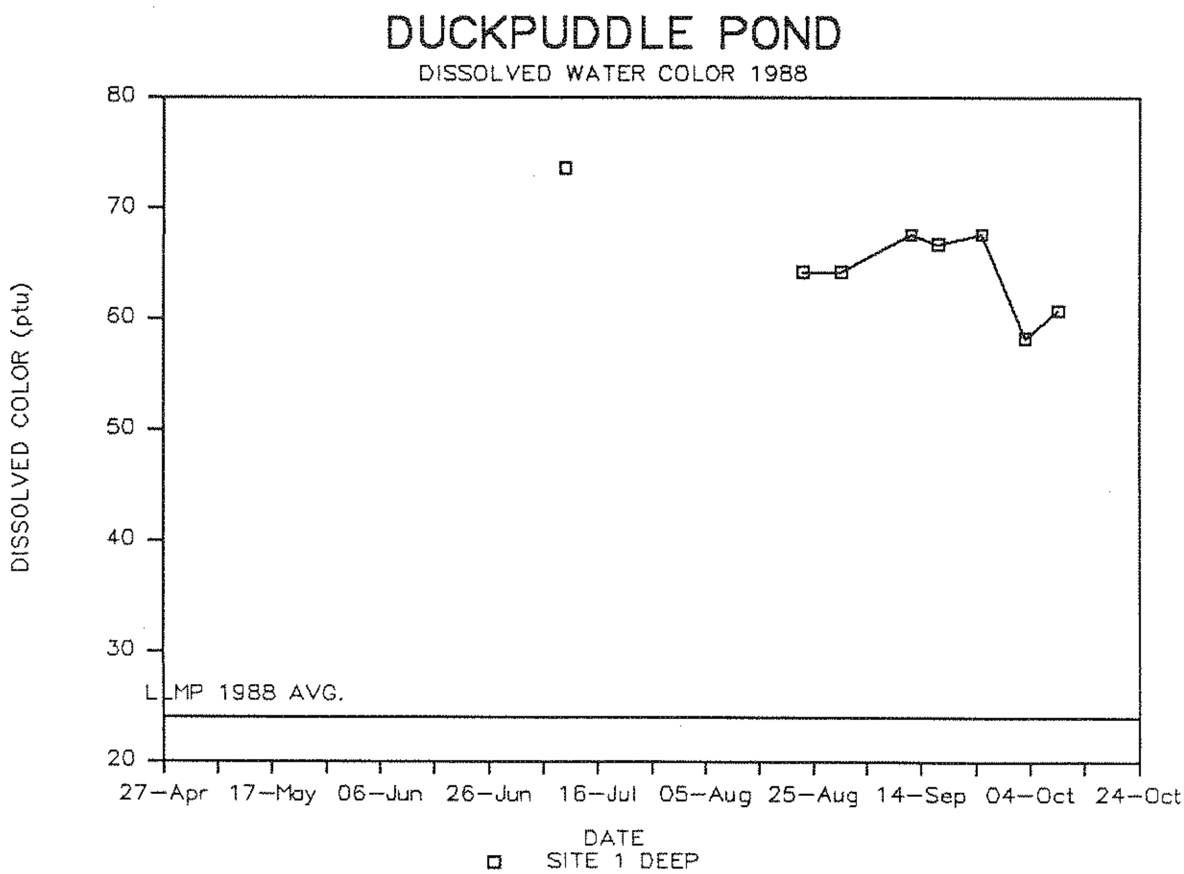


FIGURE 9- Seasonal trends in secchi disk transparency (above) Chlorophyll a concentration (top right) and dissolved color (bottom right) for Duckpuddle Pond in 1988.


DUCKPUDDLE POND
CHLOROPHYL CONCENTRATION 1988
CHLOROPHYLL a (ppb)
EUTROPHIC ^
MESOTROPHIC v
v OLIGOTROPHIC v
0
1
2
3
4
5
6
7
8
27-Apr 17-May 06-Jun 26-Jun 16-Jul 05-Aug 25-Aug 14-Sep 04-Oct 24-Oct
SITE 1 DEEP


DUCKPUDDLE POND
DISSOLVED WATER COLOR 1988
DISSOLVED COLOR (ptu)
LLMP 1988 AVG.
20
30
40
50
60
70
80
27-Apr 17-May 06-Jun 26-Jun 16-Jul 05-Aug 25-Aug 14-Sep 04-Oct 24-Oct
DATE
SITE 1 DEEP

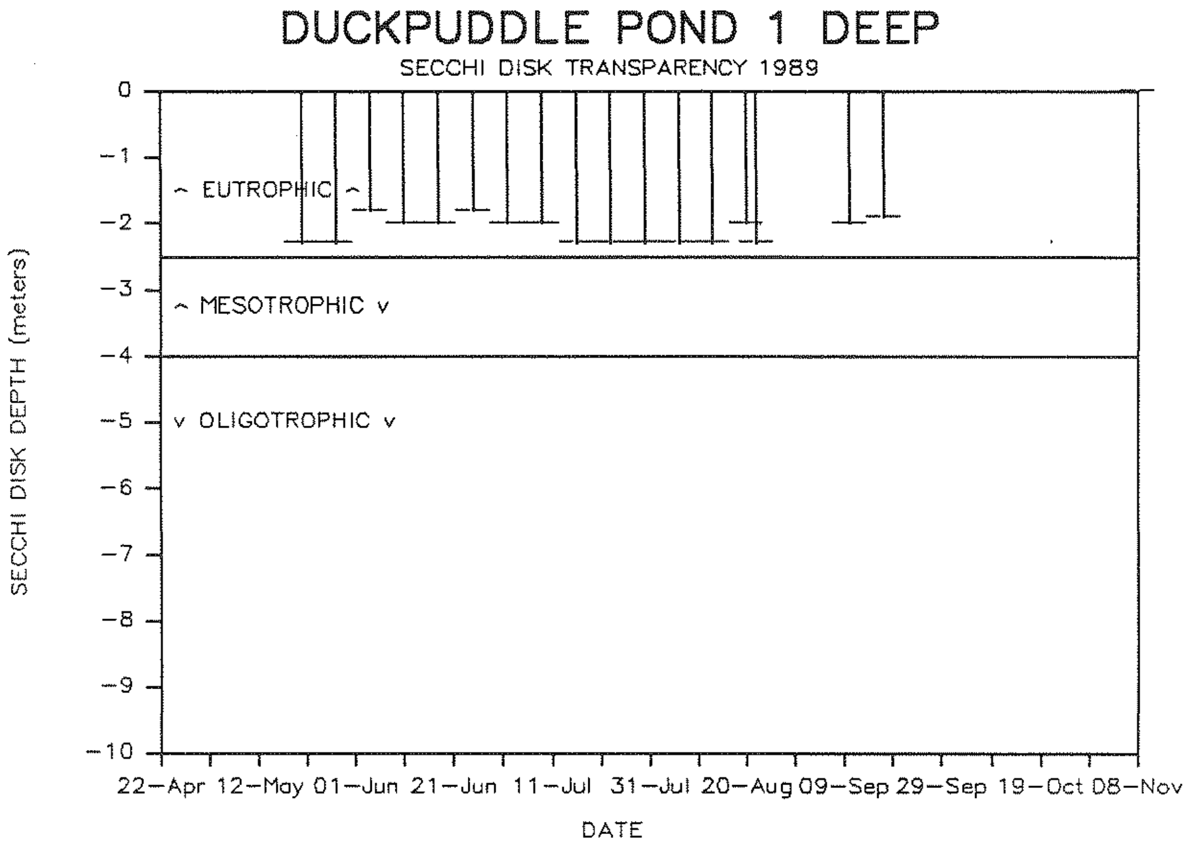
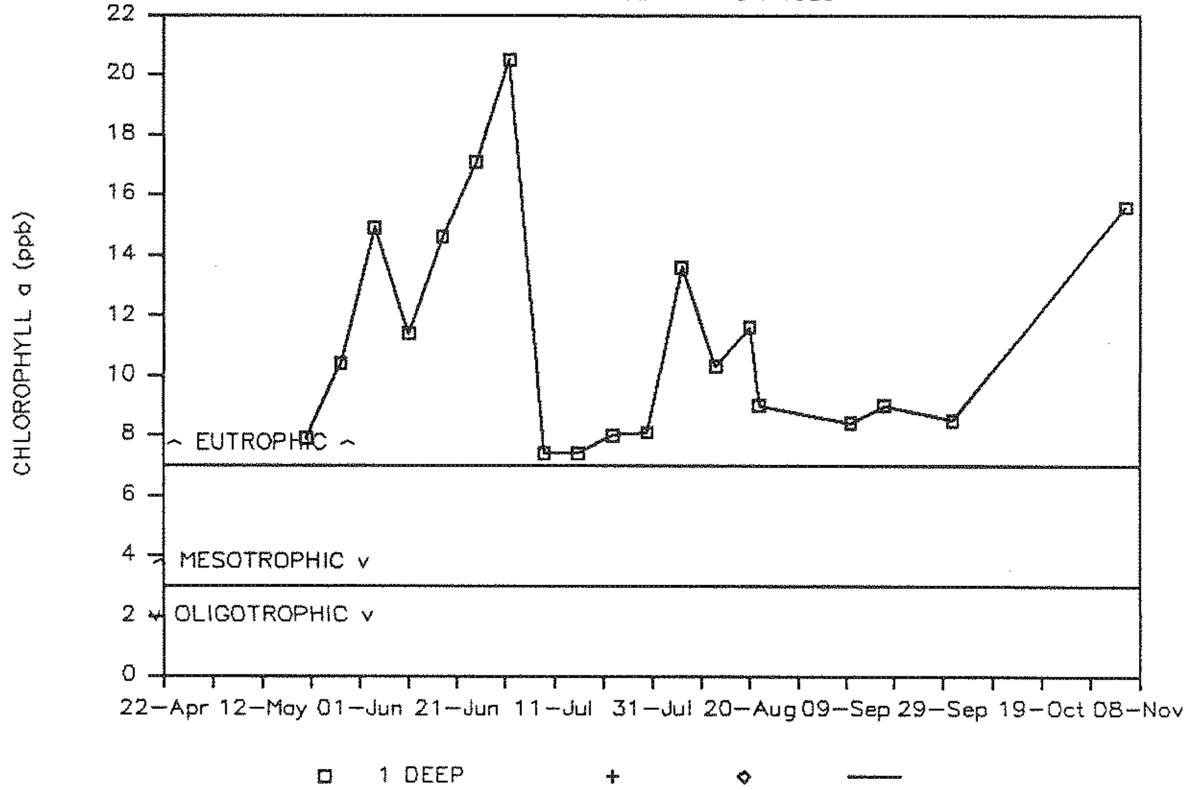


FIGURE 10- Seasonal trends in secchi disk transparency (above) Chlorophyll a concentration (top right) and dissolved color (bottom right) for Duckpuddle Pond in 1989.

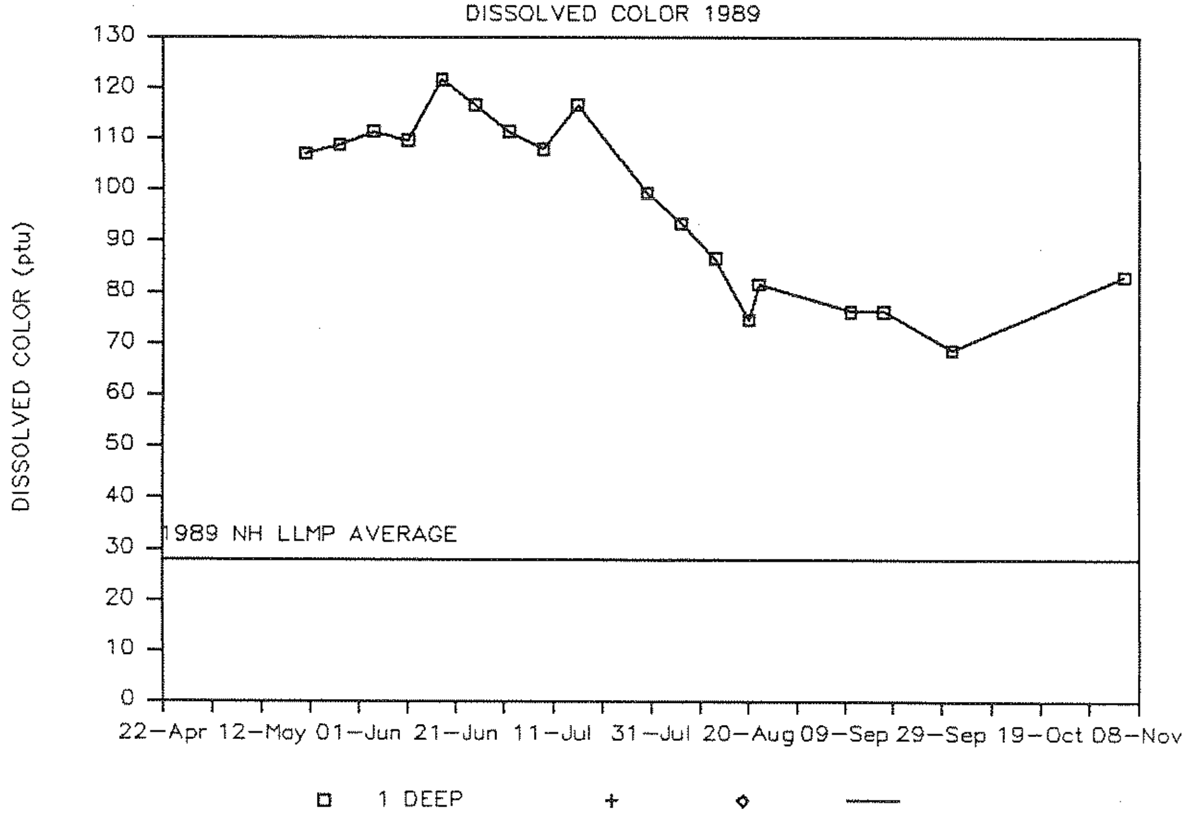
DUCKPUDDLE POND

CHLOROPHYLL CONCENTRATION 1989



DUCKPUDDLE POND

DISSOLVED COLOR 1989



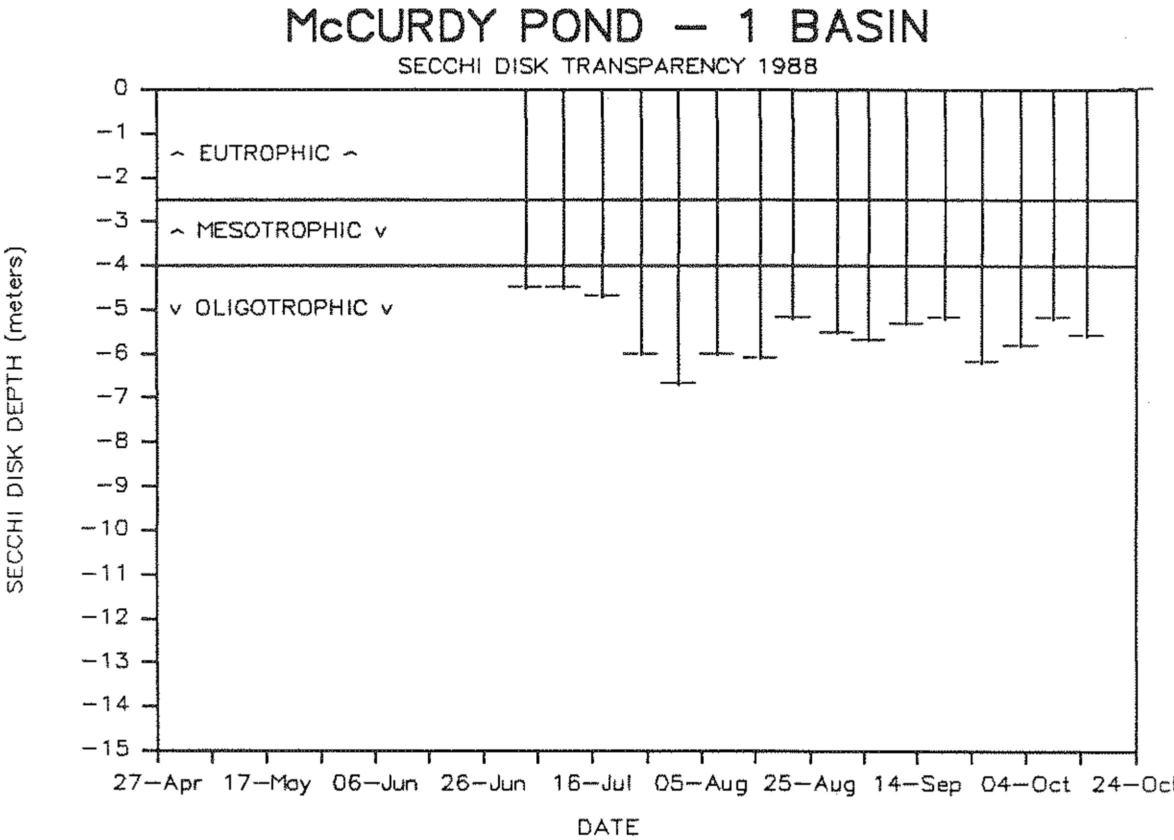
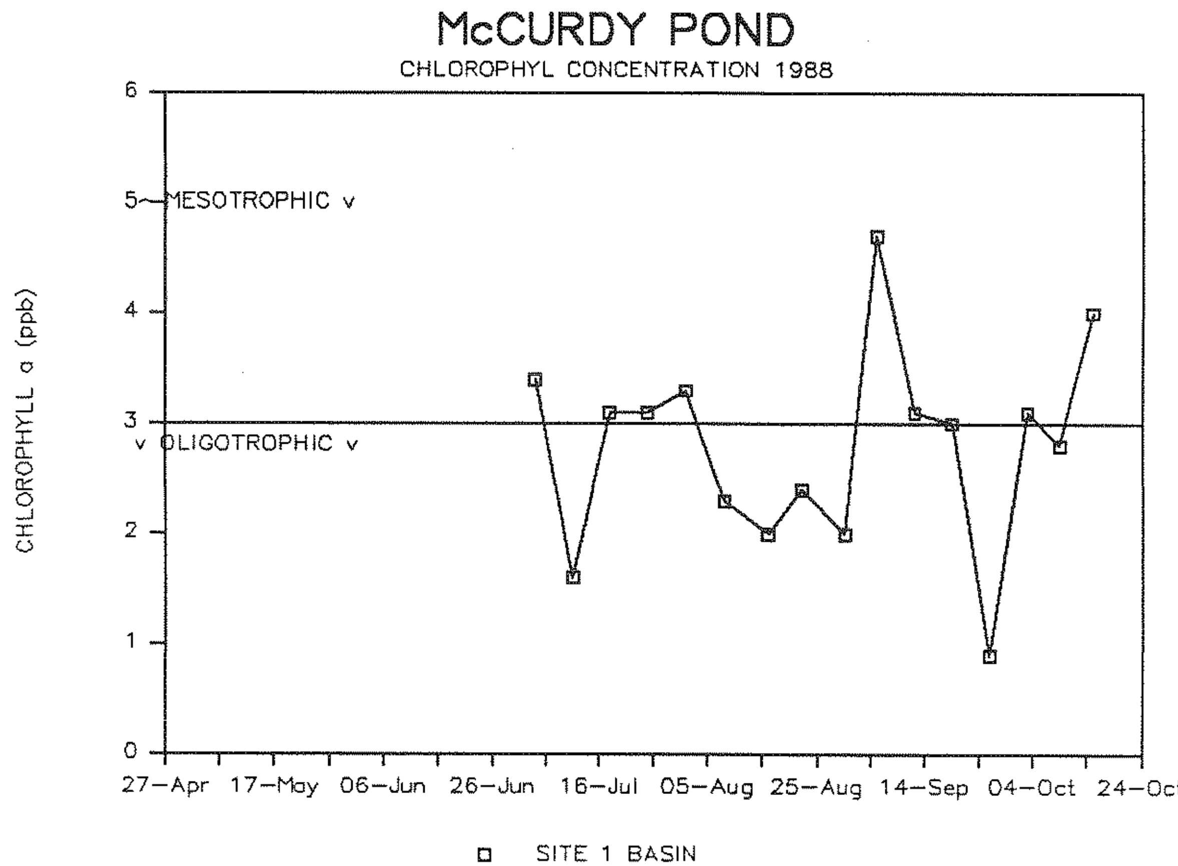
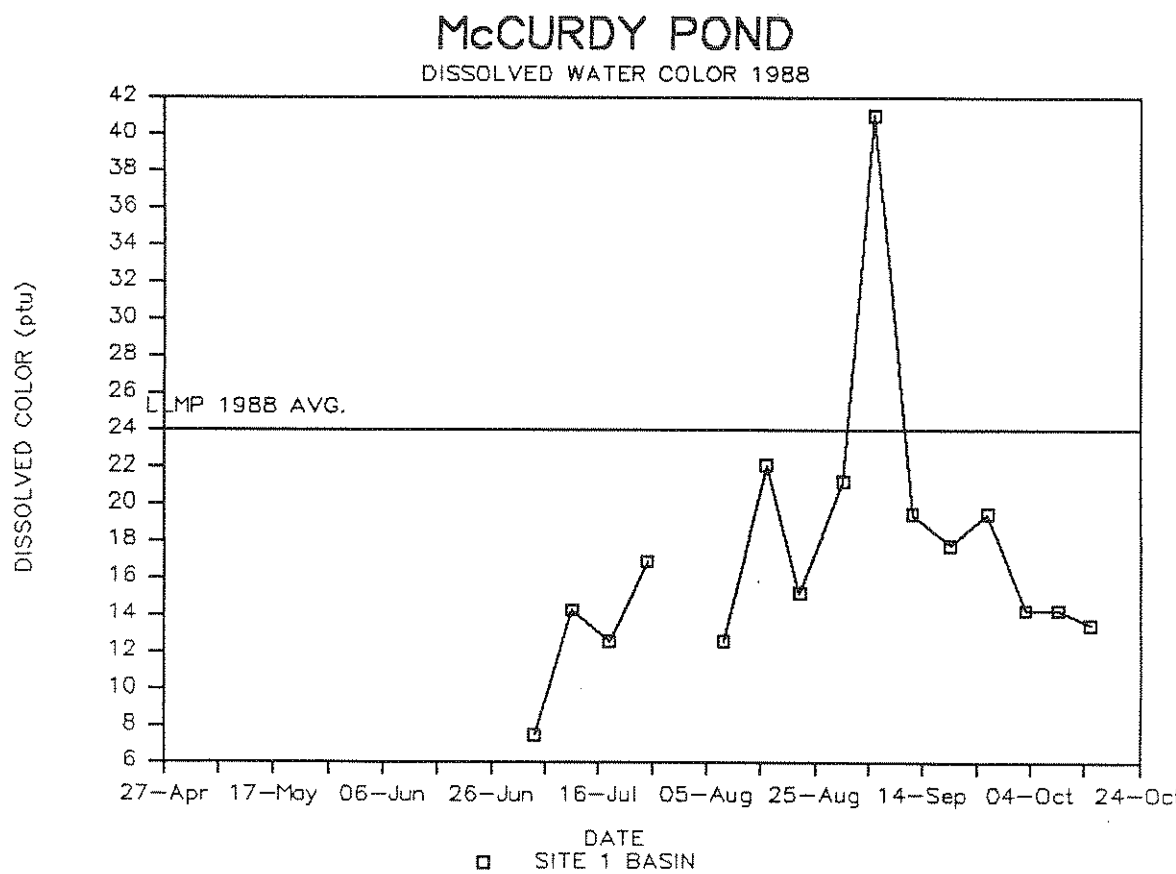


FIGURE 11- Seasonal trends in secchi disk transparency (above) Chlorophyll a concentration (top right) and dissolved color (bottom right) for McCurdy Pond in 1988.


McCURDY POND
CHLOROPHYL CONCENTRATION 1988
MESOTROPHIC v
v OLIGOTROPHIC v
CHLOROPHYLL a (ppb)
0
1
2
3
4
5
6
27-Apr 17-May 06-Jun 26-Jun 16-Jul 05-Aug 25-Aug 14-Sep 04-Oct 24-Oct
SITE 1 BASIN


McCURDY POND
DISSOLVED WATER COLOR 1988
LLMP 1988 AVG.
DISSOLVED COLOR (ptu)
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
27-Apr 17-May 06-Jun 26-Jun 16-Jul 05-Aug 25-Aug 14-Sep 04-Oct 24-Oct
DATE
SITE 1 BASIN

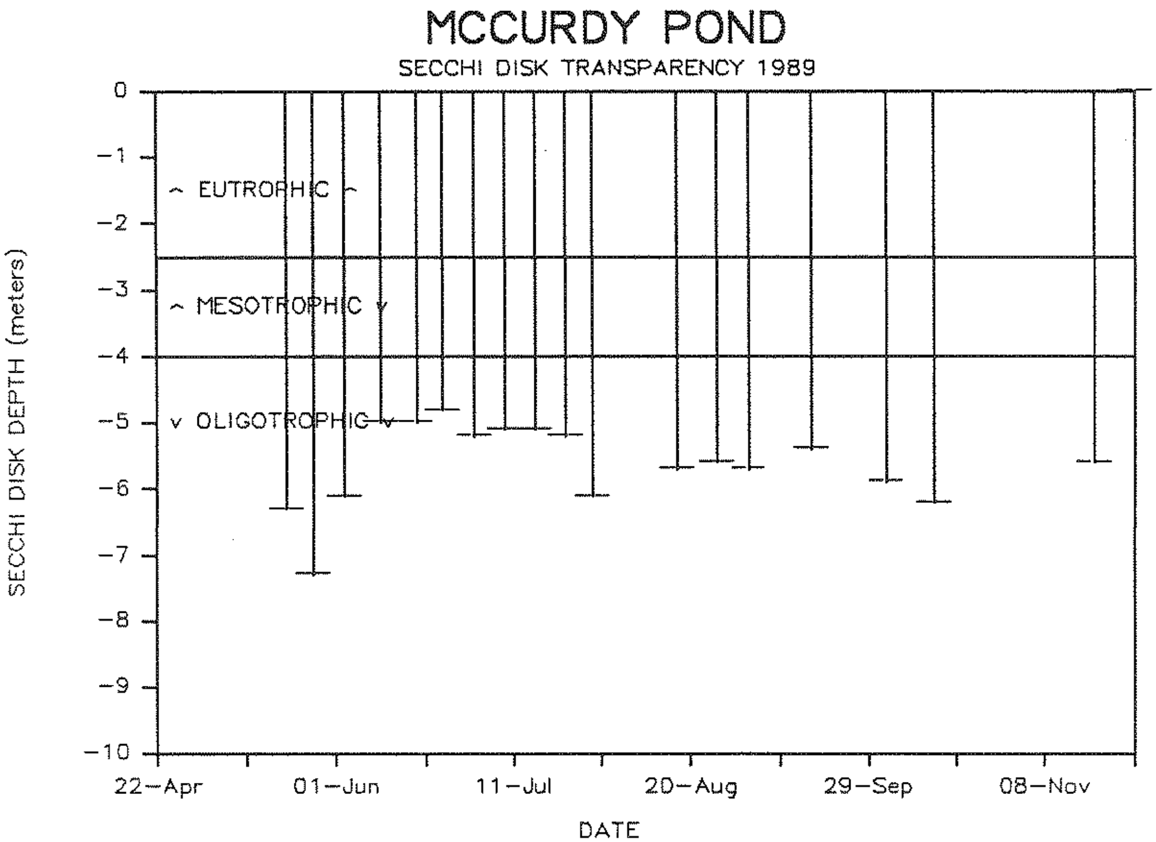
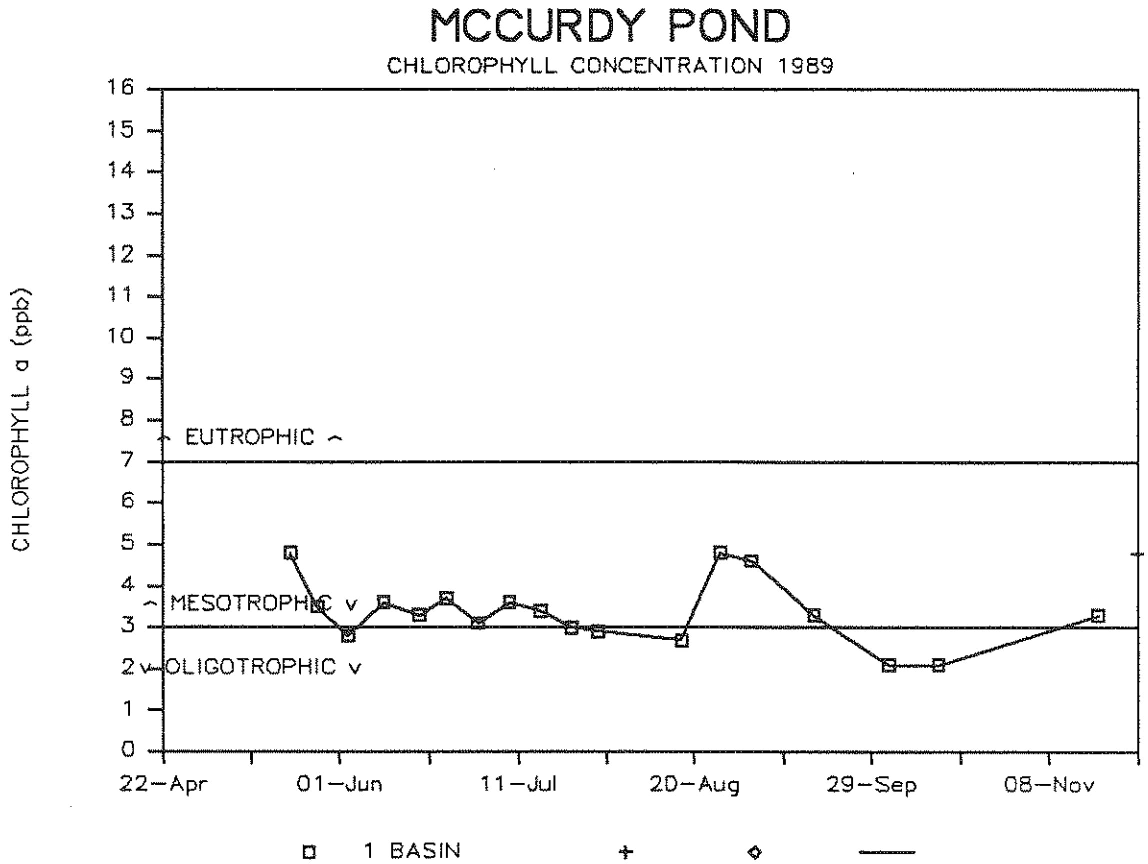
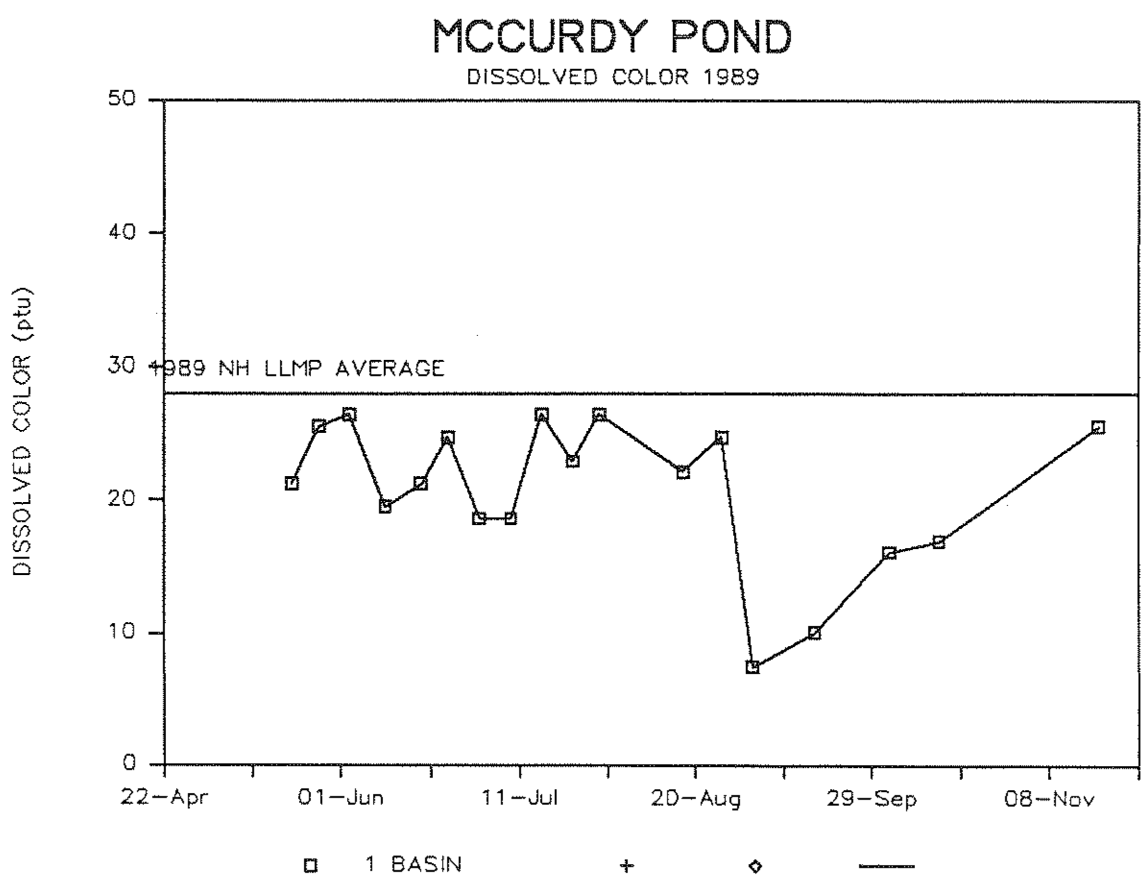


FIGURE 12- Seasonal trends in secchi disk transparency (above) Chlorophyll a concentration (top right) and dissolved color (bottom right) for McCurdy Pond in 1989.



MCCURDY POND
CHLOROPHYLL CONCENTRATION 1989
CHLOROPHYLL a (ppb)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
^ EUTROPHIC ^
^ MESOTROPHIC v
v OLIGOTROPHIC v
22-Apr
01-Jun
11-Jul
20-Aug
29-Sep
08-Nov
1 BASIN



MCCURDY POND
DISSOLVED COLOR 1989
DISSOLVED COLOR (ptu)
50
40
30
20
10
0
1989 NH LLMP AVERAGE
22-Apr
01-Jun
11-Jul
20-Aug
29-Sep
08-Nov
1 BASIN

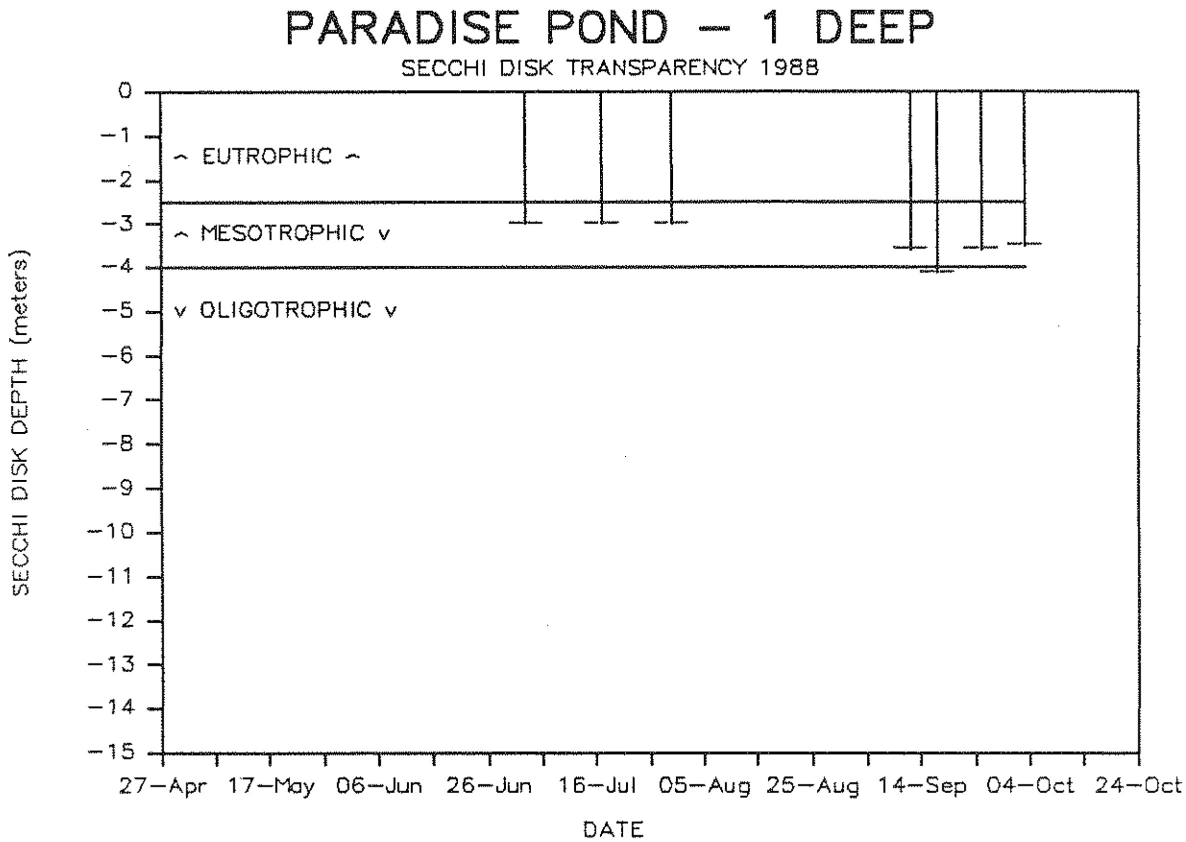
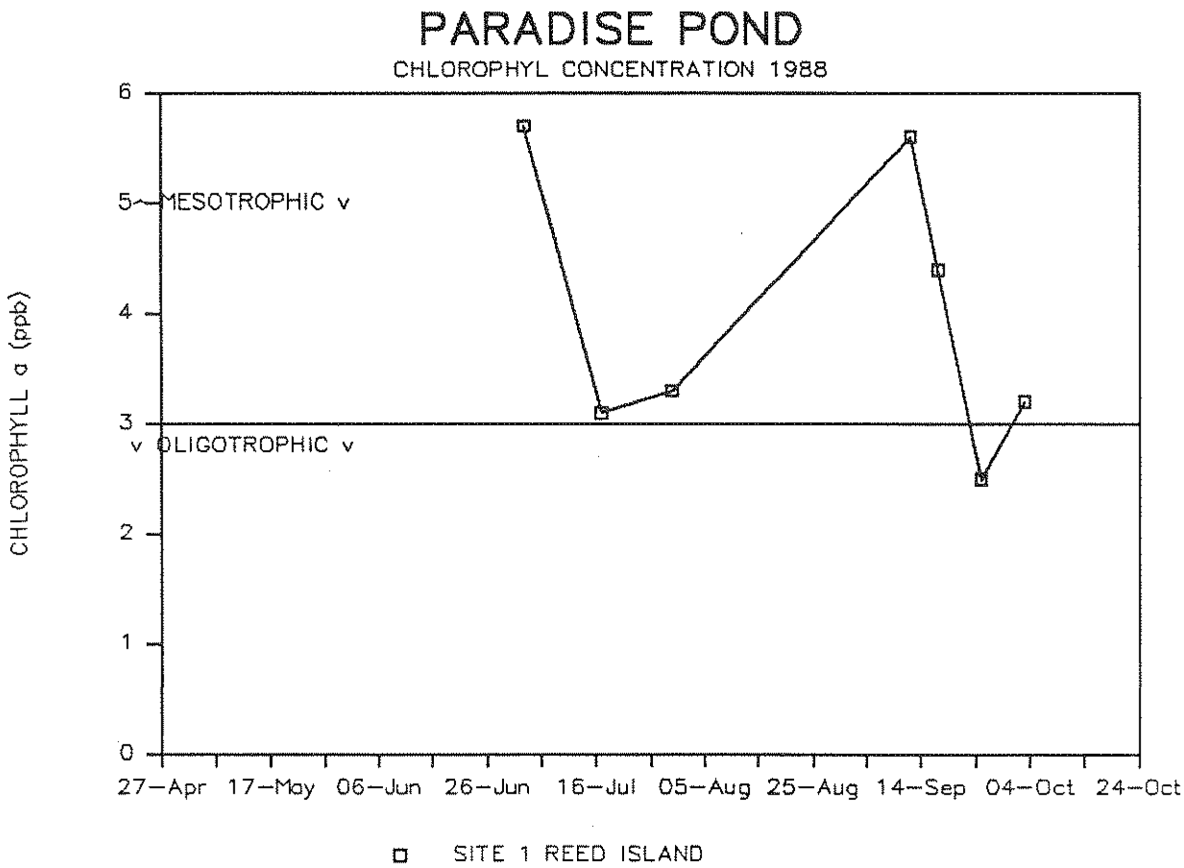
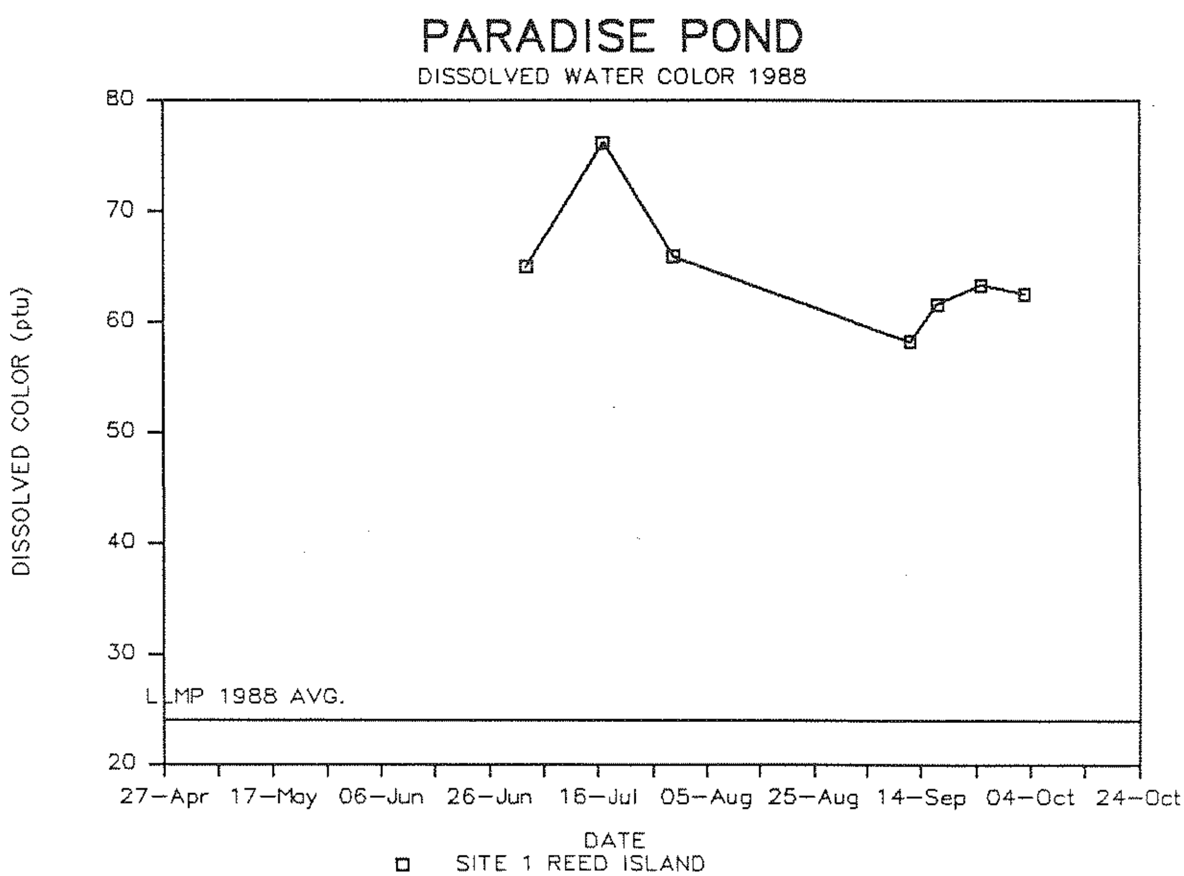


FIGURE 13- Seasonal trends in secchi disk transparency (above) Chlorophyll a concentration (top right) and dissolved color (bottom right) for Paradise Pond in 1988.


PARADISE POND
CHLOROPHYL CONCENTRATION 1988
CHLOROPHYLL a (ppb)
6
5
4
3
2
1
0
MESOTROPHIC v
v OLIGOTROPHIC v
27–Apr
17–May
06–Jun
26–Jun
16–Jul
05–Aug
25–Aug
14–Sep
04–Oct
24–Oct
SITE 1 REED ISLAND


PARADISE POND
DISSOLVED WATER COLOR 1988
DISSOLVED COLOR (ptu)
80
70
60
50
40
30
20
LLMP 1988 AVG.
27–Apr
17–May
06–Jun
26–Jun
16–Jul
05–Aug
25–Aug
14–Sep
04–Oct
24–Oct
DATE
SITE 1 REED ISLAND

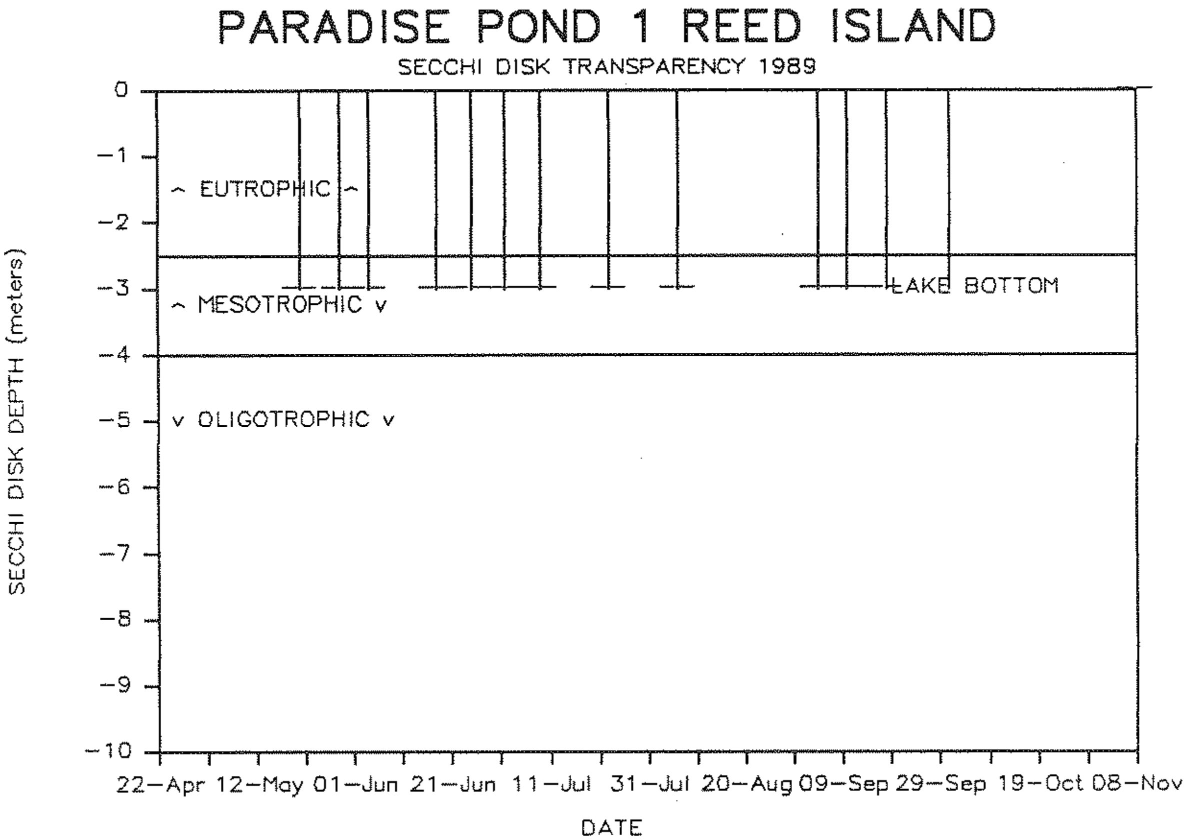
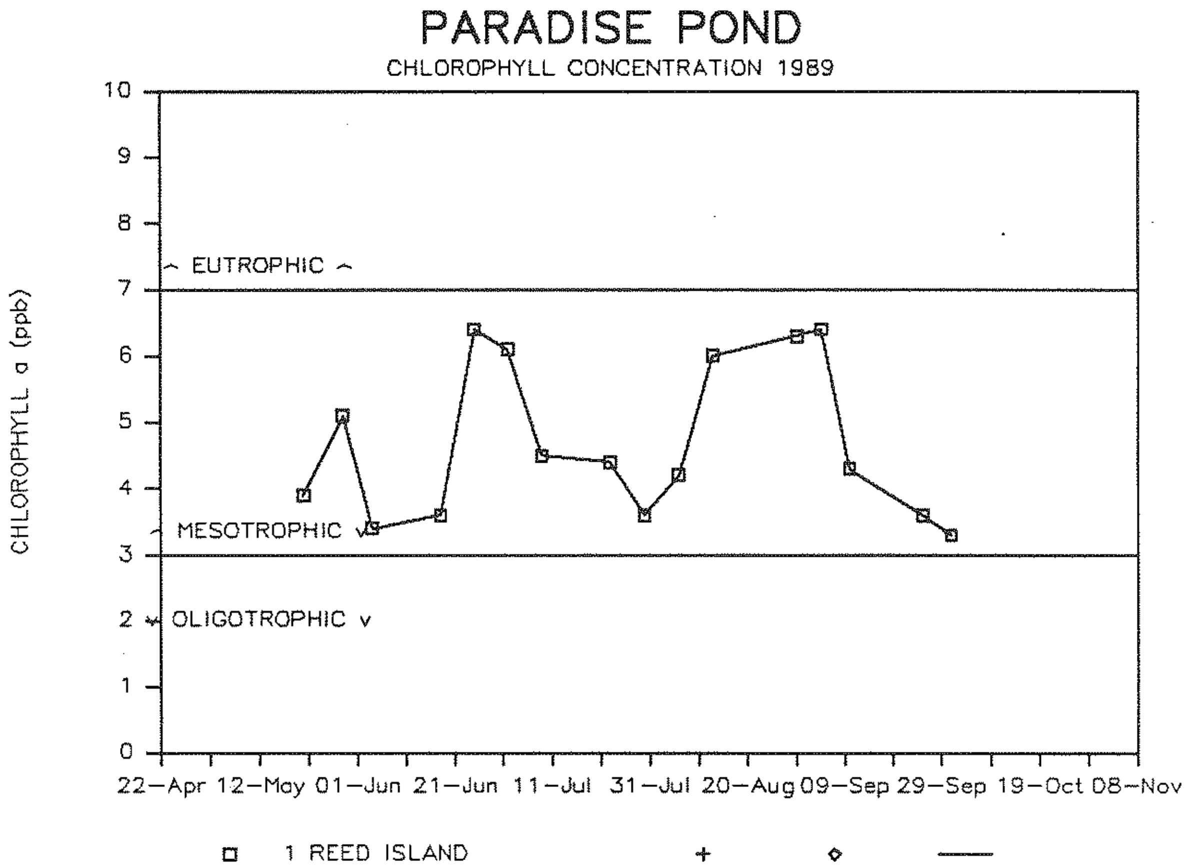
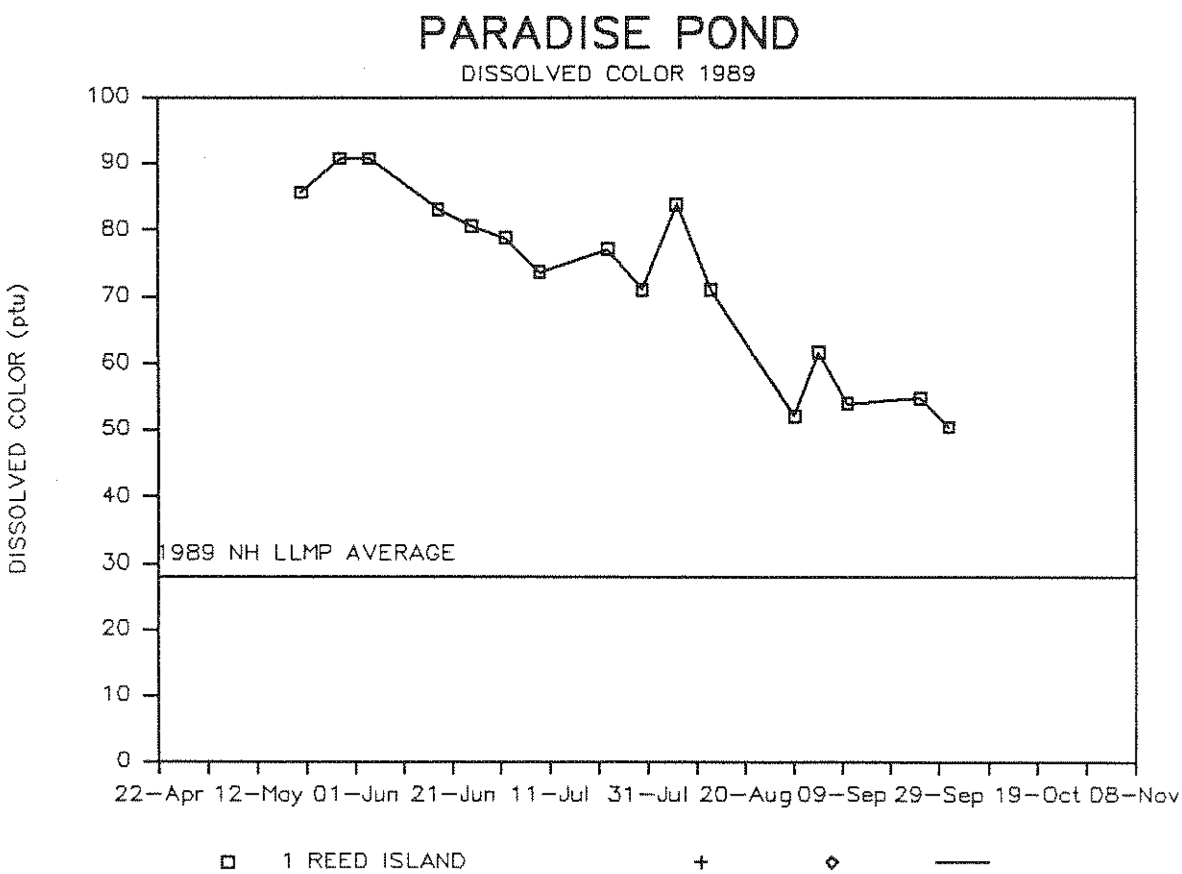


FIGURE 14- Seasonal trends in secchi disk transparency (above) Chlorophyll a concentration (top right) and dissolved color (bottom right) for Paradise Pond in 1989.


PARADISE POND
CHLOROPHYLL CONCENTRATION 1989
CHLOROPHYLL a (ppb)
^ EUTROPHIC ^
^ MESOTROPHIC v
v OLIGOTROPHIC v
0
1
2
3
4
5
6
7
8
9
10
22–Apr 12–May 01–Jun 21–Jun 11–Jul 31–Jul 20–Aug 09–Sep 29–Sep 19–Oct 08–Nov
1 REED ISLAND


PARADISE POND
DISSOLVED COLOR 1989
DISSOLVED COLOR (ptu)
1989 NH LLMP AVERAGE
0
10
20
30
40
50
60
70
80
90
100
22–Apr 12–May 01–Jun 21–Jun 11–Jul 31–Jul 20–Aug 09–Sep 29–Sep 19–Oct 08–Nov
1 REED ISLAND

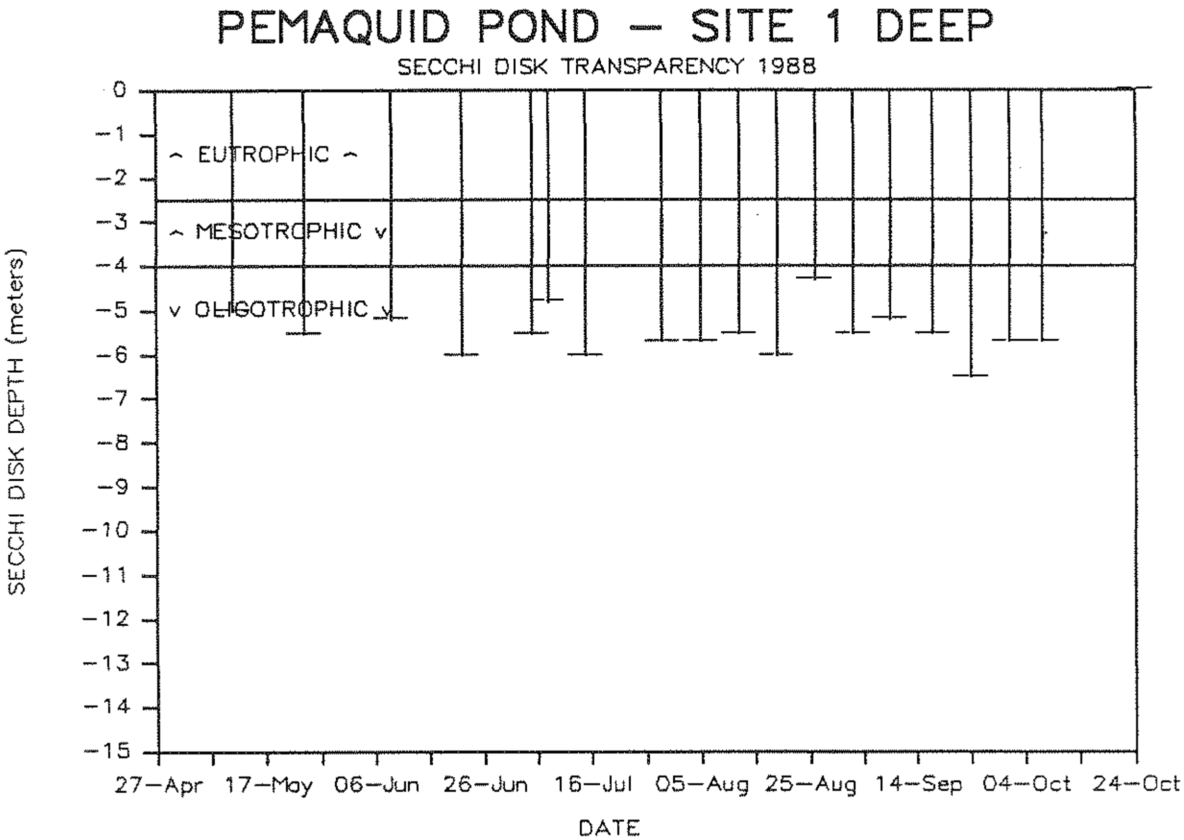
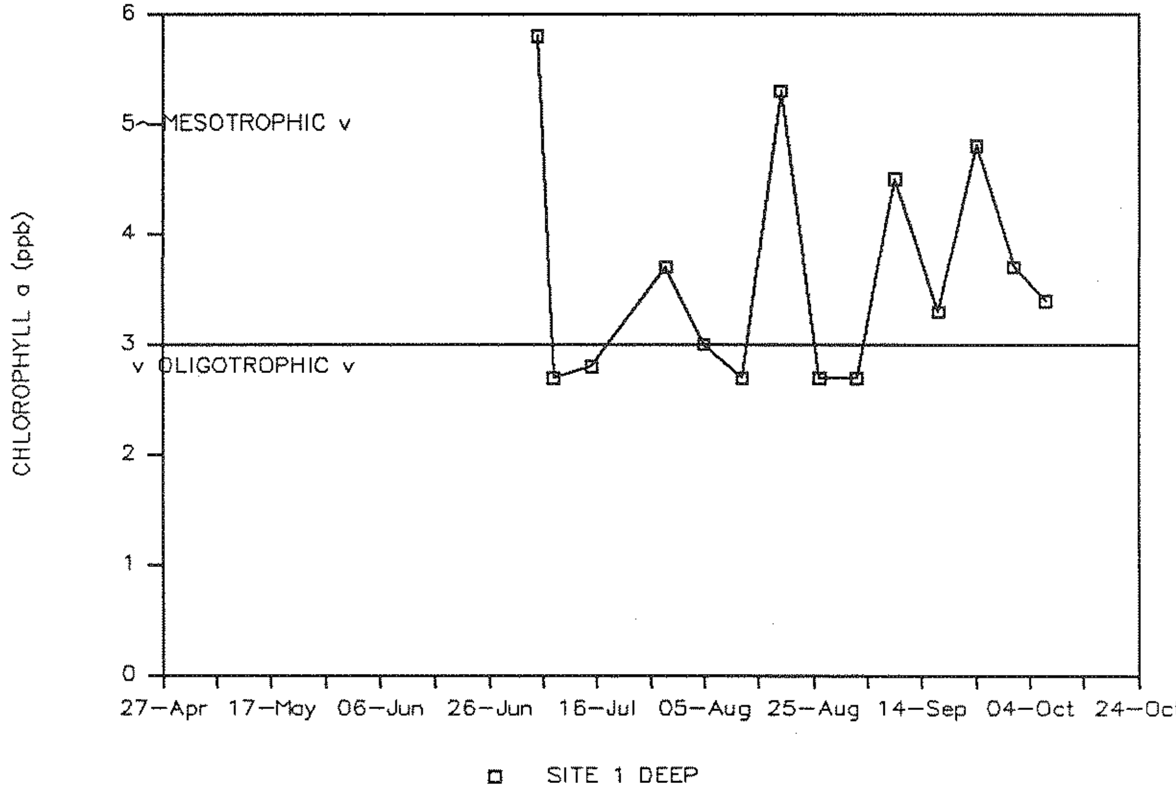


FIGURE 15- Seasonal trends in secchi disk transparency (above) Chlorophyll a concentration (top right) and dissolved color (bottom right) for Pemaquid Pond in 1988.

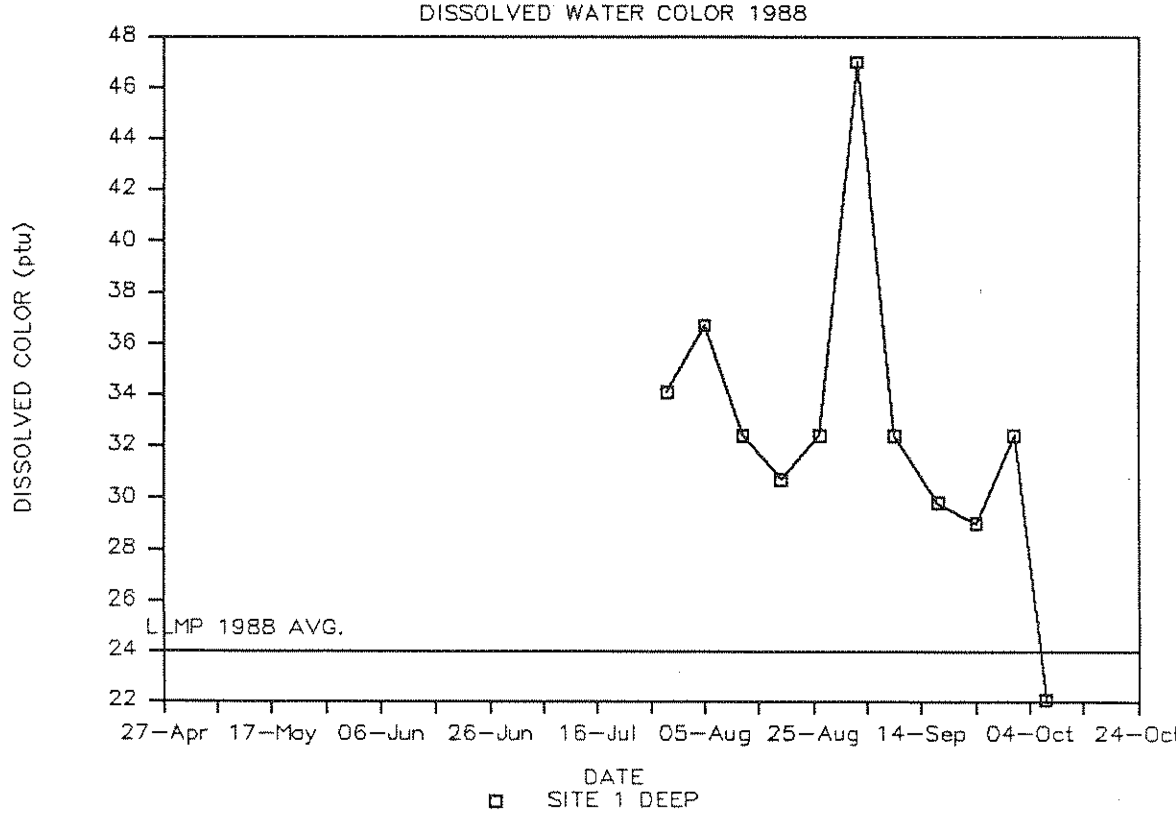
PEMAQUID POND

CHLOROPHYL CONCENTRATION 1988



PEMAQUID POND

DISSOLVED WATER COLOR 1988



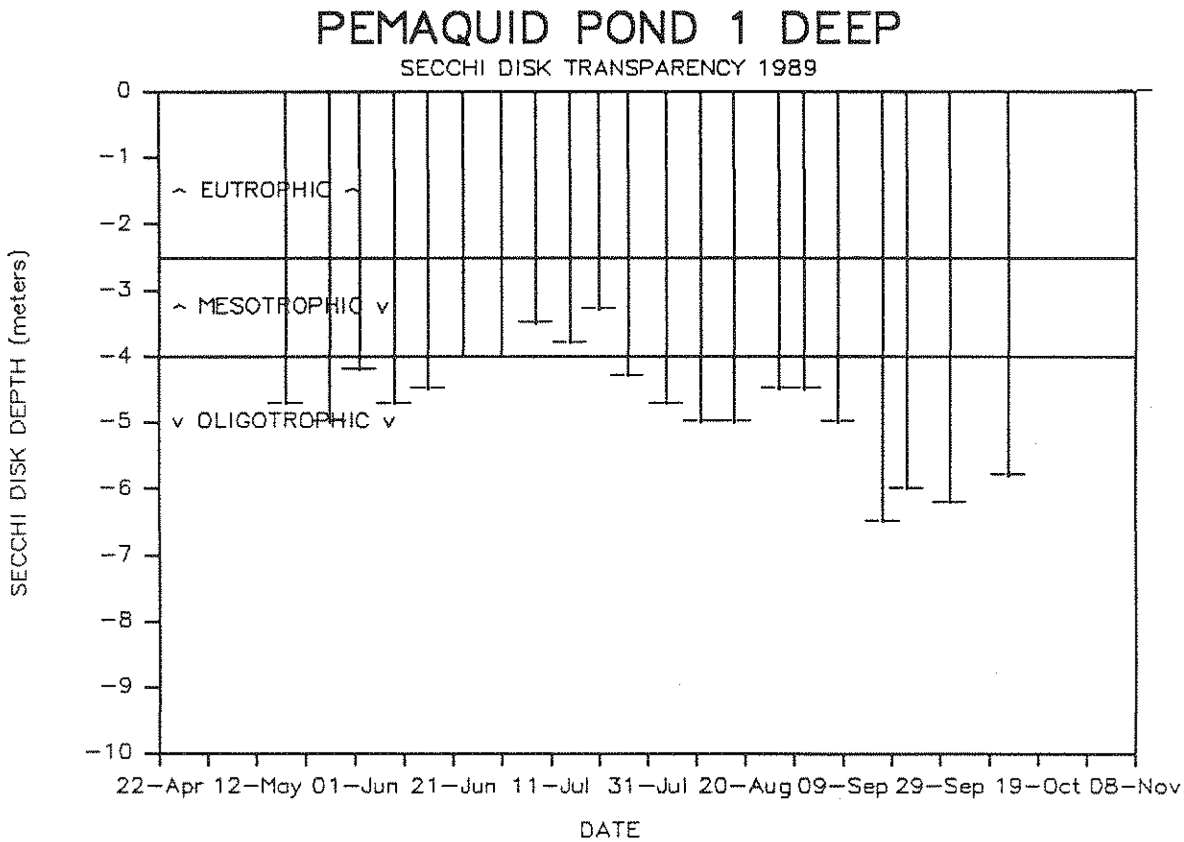
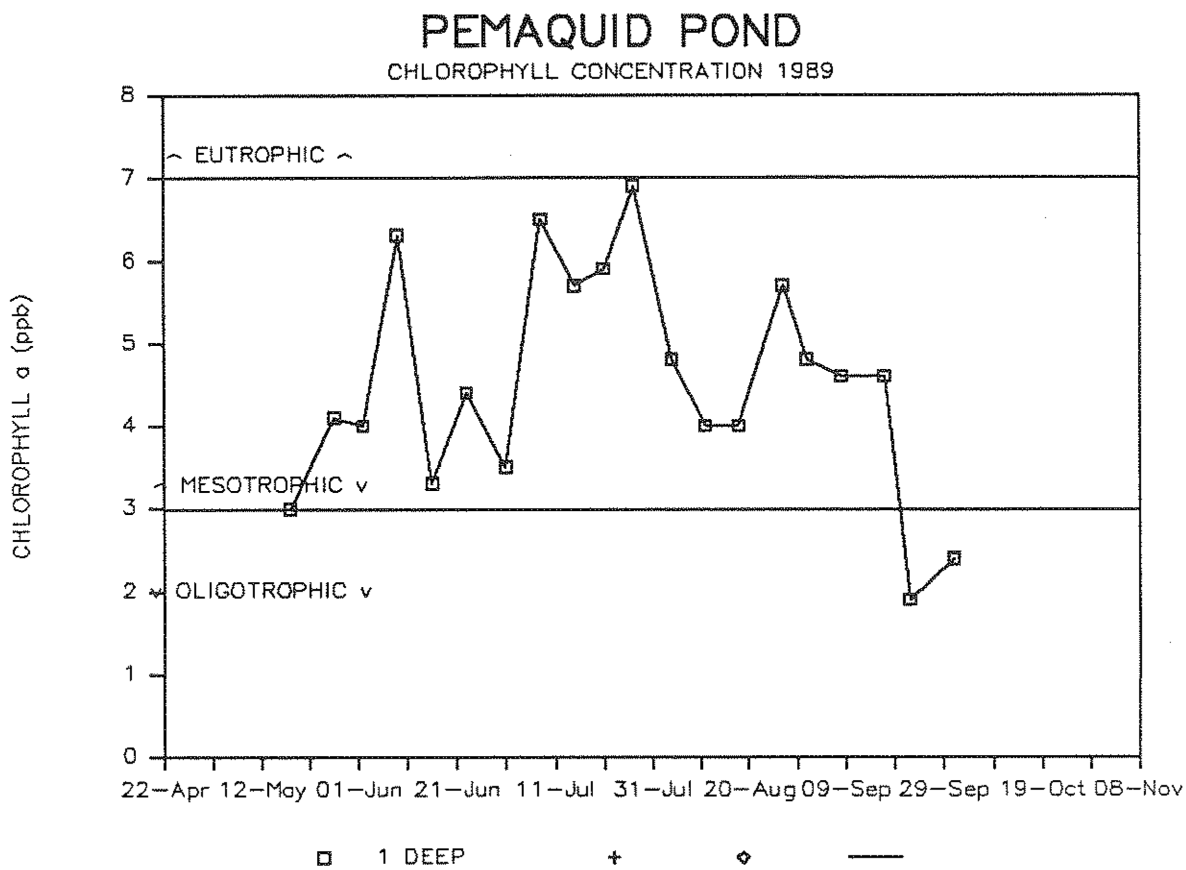
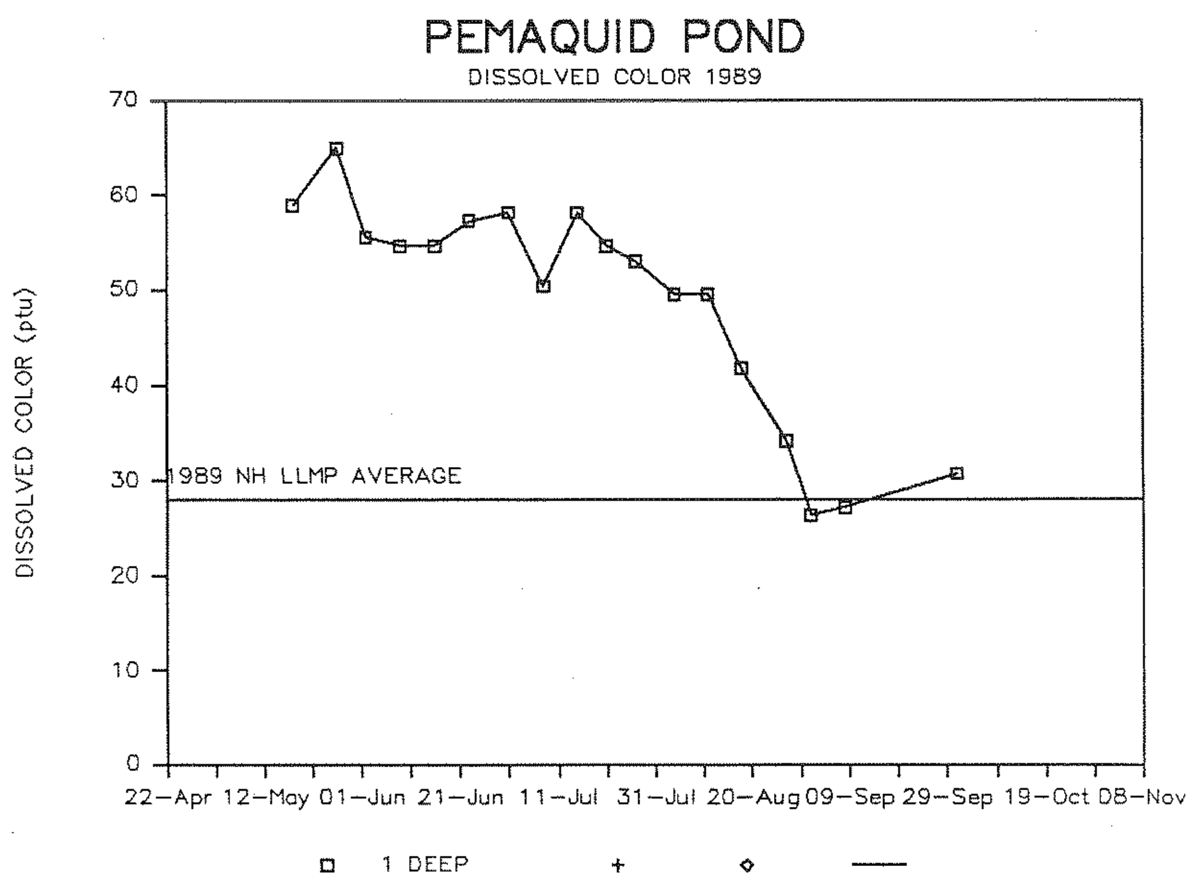


FIGURE 16- Seasonal trends in secchi disk transparency (above) Chlorophyll a concentration (top right) and dissolved color (bottom right) for Pemaquid Pond in 1989.


PEMAQUID POND
CHLOROPHYLL CONCENTRATION 1989
EUTROPHIC
MESOTROPHIC v
OLIGOTROPHIC v
CHLOROPHYLL a (ppb)
0
1
2
3
4
5
6
7
8
22-Apr 12-May 01-Jun 21-Jun 11-Jul 31-Jul 20-Aug 09-Sep 29-Sep 19-Oct 08-Nov
1 DEEP


PEMAQUID POND
DISSOLVED COLOR 1989
1989 NH LLMP AVERAGE
DISSOLVED COLOR (ptu)
0
10
20
30
40
50
60
70
22-Apr 12-May 01-Jun 21-Jun 11-Jul 31-Jul 20-Aug 09-Sep 29-Sep 19-Oct 08-Nov
1 DEEP

REFERENCES

American Public Health Association.(APHA) 1985. Standard Methods for the Examination of Water and Wastewater 16th edition. APHA, AWWA, WPCF.

Baker, A.L. 1973. Microstratification of phytoplankton in selected Minnesota lakes. Ph. D. thesis, University of Minnesota.

Carlson, R.E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22:361-379.

Forsberg, C. and S.O. Ryding. 1980. Eutrophication parameters and trophic state indices in 30 Swedish waste-water receiving lakes. Arch. Hydrobiol. 89:189-207

Gallup, D.N. 1969. Zooplankton distributions and zooplank-ton-phytoplankton relationships in a mesotrophic lake. Ph.D. Thesis, University of New Hampshire.

Haney, J.F. and D.J. Hall. 1973. Sugar-coated Daphnia: a preservation technique for Cladocera. Limnol. Oceanogr. 18:331-333.

Hutchinson, G.E. 1967. A treatise on limnology, vol. 2. John Wiley and Sons, New York.

Lind, O.T. 1979. Handbook of common methods in limnology. C.V. Mosby, St. Louis.

Lorenzen, M.W. 1980. Use of chlorophyll-Secchi disk relationships. Limnol. Oceanogr. 25:371-372.

Schindler, D.W., et al. 1985. Long-term ecosystem stress: Effects of years of experimental acidification on a small lake. Science. 228:1395-1400.

Schloss, J.A., A.L. Baker and J.F. Haney. 1990. The New Hampshire Lakes Lay Monitoring Program: development of a long-term water quality database with volunteer monitoring. Lake and Reservoir Management (in press).

Sprules, W.G. 1980. Zoogeographic patterns in size structure of zooplankton communities with possible applications to lake ecosystem modeling and management. in W.C. Kerfoot ed. Evolution and Ecology of Zooplankton Communities. University Press of New England. Dartmouth. pp642-656.

Uttermohl, H. 1958. Improvements in the quantitative methods of phytoplankton study. Mitt. int. Ver. Limnol. 9:1-25.

U.S. Environmental Protection Agency. 1979. A manual of methods for chemical analysis of water and wastes. Office of Technology Transfer, Cincinnati. PA-600/4-79-020.

Vollenweider, R.A. 1969. A manual on methods for measuring primary productivity in aquatic environments. International Biological Programme. Blackwell Scientific Publications, Oxford.

Wetzel, R.G. 1983. Limnology. Saunders College Publishing, Philadelphia.

Wetzel, R.G. and G.E. Likens. 1979. Limnological Analyses. W.B. Saunders Co. Philadelphia.

Pemaquid Lakes (Maine) Data on file as of 02/10/1990

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Pemaquid Pond, Maine
-- subset of trophic indicators, all sites, 1988

1988 SUMMARY

Average transparency:	5.5	(1988:	18	values;	4.3	-	6.5	range)
Average chlorophyll:	3.7	(1988:	14	values;	2.7	-	5.8	range)
Average phosphorus:	4.8	(1988:	3	values;	3.7	-	5.5	range)
Average color, 440:	36.3	(1988:	11	values;	25.8	-	50.7	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Deep	05/11/1988	5.0	---	---	---	---	---
1 Deep	05/24/1988	5.5	---	---	---	---	---
1 Deep	06/09/1988	5.2	---	---	---	---	---
1 Deep	06/22/1988	6.0	---	---	---	---	---
1 Deep	07/05/1988	5.5	5.8	---	---	---	---
1 Deep	07/08/1988	4.8	2.7	---	---	---	---
1 Deep	07/15/1988	6.0	2.8	---	---	---	---
1 Deep	07/29/1988	5.7	3.7	---	---	---	37.8
1 Deep	08/05/1988	5.7	3.0	---	---	---	40.4
1 Deep	08/12/1988	5.5	2.7	---	---	---	36.1
1 Deep	08/19/1988	6.0	5.3	---	---	---	34.4
1 Deep	08/26/1988	4.3	2.7	---	---	---	36.1
1 Deep	09/02/1988	5.5	2.7	---	---	---	50.7
1 Deep	09/09/1988	5.2	4.5	---	---	---	36.1
1 Deep	09/17/1988	5.5	3.3	---	---	---	33.5
1 Deep	09/24/1988	6.5	4.8	---	---	---	32.6
1 Deep	10/01/1988	5.7	3.7	---	---	---	36.1
1 Deep	10/07/1988	5.7	3.4	---	---	---	25.8
2 Inlet	07/16/1988	---	---	5.5	---	---	---
2 Inlet	08/24/1988	---	---	5.3	---	---	---
2 Inlet	09/24/1988	---	---	3.7	---	---	---

<< End of 1988 listing, 21 records >>

Pemaquid Lakes (Maine) Data on file as of 02/10/1990

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Duckpuddle Pond, Maine
-- subset of trophic indicators, all sites, 1988

1988 SUMMARY

Average transparency:	3.1	(1988:	12	values;	2.6	-	3.7	range)
Average chlorophyll:	5.2	(1988:	11	values;	1.1	-	7.9	range)
Average color, 440:	72.6	(1988:	2	values;	67.9	-	77.3	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray). ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Basin	07/03/1988	3.3	1.1	---	---	---	---
1 Basin	07/10/1988	3.4	4.6	---	---	---	77.3
1 Basin	07/29/1988	3.5	1.1	---	---	---	---
1 Basin	08/08/1988	3.7	2.7	---	---	---	---
1 Basin	08/23/1988	2.6	6.8	---	---	---	---
1 Basin	08/30/1988	2.9	5.9	---	---	---	67.9
1 Basin	09/12/1988	2.6	7.7	---	---	---	---
1 Basin	09/17/1988	3.1	7.3	---	---	---	---
1 Basin	09/25/1988	3.1	7.6	---	---	---	---
1 Basin	10/03/1988	3.0	4.4	---	---	---	---
1 Basin	10/09/1988	3.0	7.9	---	---	---	---
1 Basin	10/15/1988	2.8	---	---	---	---	---

<< End of 1988 listing, 12 records >>

Pemaquid Lakes (Maine) Data on file as of 02/10/1990

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

McCurdy Pond, Maine
-- subset of trophic indicators, all sites, 1988

1988 SUMMARY

Average transparency:	5.5	(1988:	16	values;	4.5 -	6.7	range)
Average chlorophyll:	2.8	(1988:	16	values;	0.9 -	4.7	range)
Average color, 440:	21.2	(1988:	15	values;	11.2 -	44.7	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Basin	07/04/1988	4.5	3.4	---	---	---	11.2
1 Basin	07/11/1988	4.5	1.6	---	---	---	18.0
1 Basin	07/18/1988	4.7	3.1	---	---	---	16.3
1 Basin	07/25/1988	6.0	3.1	---	---	---	20.6
1 Basin	08/01/1988	6.7	3.3	---	---	---	---
1 Basin	08/08/1988	6.0	2.3	---	---	---	16.3
1 Basin	08/16/1988	6.1	2.0	---	---	---	25.8
1 Basin	08/22/1988	5.2	2.4	---	---	---	18.9
1 Basin	08/30/1988	5.5	2.0	---	---	---	24.9
1 Basin	09/05/1988	5.7	4.7	---	---	---	44.7
1 Basin	09/12/1988	5.3	3.1	---	---	---	23.2
1 Basin	09/19/1988	5.2	3.0	---	---	---	21.5
1 Basin	09/26/1988	6.2	0.9	---	---	---	23.2
1 Basin	10/03/1988	5.8	3.1	---	---	---	18.0
1 Basin	10/09/1988	5.2	2.8	---	---	---	18.0
1 Basin	10/15/1988	5.6	4.0	---	---	---	17.2

<< End of 1988 listing, 16 records >>

Pemaquid Lakes (Maine) Data on file as of 02/10/1990

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Biscay Pond, Maine
-- subset of trophic indicators, all sites, 1988

1988 SUMMARY

Average transparency:	3.9	(1988:	5 values;	3.2 -	4.6	range)
Average chlorophyll:	3.0	(1988:	6 values;	2.1 -	4.8	range)
Average phosphorus:	6.4	(1988:	3 values;	2.6 -	11.7	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 North	07/10/1988	---	3.4	---	---	---	---
1 North	07/31/1988	4.6	2.1	---	---	---	---
1 North	08/07/1988	4.0	2.3	---	---	---	---
1 North	08/15/1988	3.9	4.8	---	---	---	---
1 North	08/27/1988	4.0	2.1	---	---	---	---
1 North	09/07/1988	3.2	3.4	---	---	---	---
2 Inlet	07/09/1988	---	---	2.6	---	---	---
2 Inlet	08/24/1988	---	---	4.9	---	---	---
2 Inlet	09/25/1988	---	---	11.7	---	---	---

<< End of 1988 listing, 9 records >>

Pemaquid Lakes (Maine) Data on file as of 02/10/1990

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Paradise Pond, Maine
-- subset of trophic indicators, all sites, 1988

1988 SUMMARY

Average transparency:	3.4	(1988:	7 values;	3.0 -	4.1	range)
Average chlorophyll:	4.0	(1988:	7 values;	2.5 -	5.7	range)
Average color, 440:	68.4	(1988:	7 values;	61.8 -	79.9	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Reedls.	07/03/1988	3.0	5.7	---	---	---	68.7
1 Reedls.	07/17/1988	3.0	3.1	---	---	---	79.9
1 Reedls.	07/30/1988	3.0	3.3	---	---	---	69.6
1 Reedls.	09/12/1988	3.6	5.6	---	---	---	61.8
1 Reedls.	09/17/1988	4.1	4.4	---	---	---	65.3
1 Reedls.	09/25/1988	3.6	2.5	---	---	---	67.0
1 Reedls.	10/03/1988	3.5	3.2	---	---	---	66.1

<< End of 1988 listing, 7 records >>

Pemaquid Lakes (Maine) Data on file as of 02/10/1990

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Pemaquid Pond, Maine
-- subset of trophic indicators, all sites, 1989

1989 SUMMARY

Average transparency:	4.7	(1989:	21	values;	3.3	-	6.5 range)
Average chlorophyll:	4.5	(1989:	20	values;	1.9	-	6.9 range)
Average phosphorus:	7.0	(1989:	3	values;	3.5	-	10.4 range)
Average color, 440:	48.9	(1989:	18	values;	26.4	-	65.0 range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Deep	05/09/1989	---	---	3.5	---	---	---
1 Deep	05/18/1989	4.7	3.0	---	---	---	59.0
1 Deep	05/27/1989	5.0	4.1	---	---	---	65.0
1 Deep	06/02/1989	4.2	4.0	---	---	---	55.6
1 Deep	06/09/1989	4.7	6.3	---	---	---	54.7
1 Deep	06/16/1989	4.5	3.3	---	---	---	54.7
1 Deep	06/23/1989	4.0	4.4	---	---	---	57.3
1 Deep	07/01/1989	4.0	3.5	---	---	---	58.2
1 Deep	07/08/1989	3.5	6.5	---	---	---	50.4
1 Deep	07/15/1989	3.8	5.7	10.4	---	---	58.2
1 Deep	07/21/1989	3.3	5.9	---	---	---	54.7
1 Deep	07/27/1989	4.3	6.9	---	---	---	53.0
1 Deep	08/04/1989	4.7	4.8	---	---	---	49.6
1 Deep	08/11/1989	5.0	4.0	---	---	---	49.6
1 Deep	08/18/1989	5.0	4.0	---	---	---	41.8
1 Deep	08/27/1989	4.5	5.7	---	---	---	34.1
1 Deep	09/01/1989	4.5	4.8	---	---	---	26.4
1 Deep	09/08/1989	5.0	4.6	---	---	---	27.2
1 Deep	09/17/1989	6.5	4.6	7.1	---	---	---
1 Deep	09/22/1989	6.0	1.9	---	---	---	---
1 Deep	10/01/1989	6.2	2.4	---	---	---	30.7
1 Deep	10/13/1989	5.8	---	---	---	---	---

<< End of 1989 listing, 22 records >>

Pemaquid Lakes (Maine) Data on file as of 02/10/1990

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Duckpuddle Pond, Maine
-- subset of trophic indicators, all sites, 1989

1989 SUMMARY

Average transparency:	2.1	(1989:	19 values;	1.8	-	2.3	range)
Average chlorophyll:	11.2	(1989:	19 values;	7.4	-	20.5	range)
Average phosphorus:	6.7	(1989:	3 values;	5.7	-	7.9	range)
Average color, 440:	97.2	(1989:	18 values;	68.5	-	121.7	range)

Site	Date	Trans- parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Basin	05/09/1989	---	---	5.7	---	---	---
1 Basin	05/21/1989	2.3	7.9	---	---	---	107.1
1 Basin	05/28/1989	2.3	10.4	---	---	---	108.8
1 Basin	06/04/1989	1.8	14.9	---	---	---	111.4
1 Basin	06/11/1989	2.0	11.4	---	---	---	109.7
1 Basin	06/18/1989	2.0	14.6	---	---	---	121.7
1 Basin	06/25/1989	1.8	17.1	---	---	---	116.6
1 Basin	07/02/1989	2.0	20.5	---	---	---	111.4
1 Basin	07/09/1989	2.0	7.4	---	---	---	108.0
1 Basin	07/16/1989	2.3	7.4	6.6	---	---	116.6
1 Basin	07/23/1989	2.3	8.0	---	---	---	---
1 Basin	07/30/1989	2.3	8.1	---	---	---	99.4
1 Basin	08/06/1989	2.3	13.6	---	---	---	93.4
1 Basin	08/13/1989	2.3	10.3	---	---	---	86.5
1 Basin	08/20/1989	2.0	11.6	---	---	---	74.5
1 Basin	08/27/1989	2.3	9.0	---	---	---	81.4
1 Basin	09/10/1989	2.0	8.4	---	---	---	76.2
1 Basin	09/17/1989	1.9	9.0	7.9	---	---	76.2
1 Basin	10/01/1989	2.3	8.5	---	---	---	68.5
1 Basin	11/05/1989	2.0	15.6	---	---	---	83.0

<< End of 1989 listing, 20 records >>

Pemaquid Lakes (Maine) Data on file as of 02/10/1990

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

McCurdy Pond, Maine
-- subset of trophic indicators, all sites, 1989

1989 SUMMARY

Average transparency:	5.6	(1989: 18 values;	4.8	-	7.3	range)
Average chlorophyll:	3.4	(1989: 18 values;	2.1	-	4.8	range)
Average phosphorus:	3.7	(1989: 3 values;	0.9	-	6.8	range)
Average color, 440:	20.8	(1989: 18 values;	7.5	-	26.4	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Basin	05/09/1989	---	---	6.8	---	---	---
1 Basin	05/21/1989	6.3	4.8	---	---	---	21.2
1 Basin	05/27/1989	7.3	3.5	---	---	---	25.5
1 Basin	06/03/1989	6.1	2.8	---	---	---	26.4
1 Basin	06/11/1989	5.0	3.6	---	---	---	19.5
1 Basin	06/19/1989	5.0	3.3	---	---	---	21.2
1 Basin	06/25/1989	4.8	3.7	---	---	---	24.7
1 Basin	07/02/1989	5.2	3.1	---	---	---	18.6
1 Basin	07/09/1989	5.1	3.6	---	---	---	18.6
1 Basin	07/16/1989	5.1	3.4	0.9	---	---	26.4
1 Basin	07/23/1989	5.2	3.0	---	---	---	22.9
1 Basin	07/29/1989	6.1	2.9	---	---	---	26.4
1 Basin	08/17/1989	5.7	2.7	---	---	---	22.1
1 Basin	08/26/1989	5.6	4.8	---	---	---	24.7
1 Basin	09/02/1989	5.7	4.6	---	---	---	7.5
1 Basin	09/16/1989	5.4	3.3	3.5	---	---	10.1
1 Basin	10/03/1989	5.9	2.1	---	---	---	16.1
1 Basin	10/14/1989	6.2	2.1	---	---	---	16.9
1 Basin	11/19/1989	5.6	3.3	---	---	---	25.5

<< End of 1989 listing, 19 records >>

Pemaquid Lakes (Maine) Data on file as of 02/10/1990

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Biscay Pond, Maine
-- subset of trophic indicators, all sites, 1989

1989 SUMMARY

Average transparency:	5.2	(1989:	19 values;	4.5	-	6.5	range)
Average chlorophyll:	4.2	(1989:	19 values;	2.4	-	7.4	range)
Average phosphorus:	4.3	(1989:	3 values;	2.2	-	6.2	range)
Average color, 440:	40.4	(1989:	19 values;	26.4	-	53.6	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 North	05/09/1989	---	---	6.2	---	---	---
1 North	05/27/1989	5.0	6.5	---	---	---	46.1
1 North	06/03/1989	4.7	4.6	---	---	---	48.7
1 North	06/11/1989	4.5	2.9	---	---	---	45.3
1 North	06/18/1989	4.5	3.4	---	---	---	47.0
1 North	06/25/1989	4.5	2.8	---	---	---	47.8
1 North	07/03/1989	4.9	3.1	---	---	---	46.1
1 North	07/09/1989	5.5	3.7	---	---	---	41.0
1 North	07/16/1989	5.3	4.1	4.4	---	---	53.6
1 North	07/22/1989	5.0	4.1	---	---	---	48.7
1 North	07/30/1989	5.2	7.4	---	---	---	44.4
1 North	08/06/1989	4.8	2.4	---	---	---	40.1
1 North	08/14/1989	4.8	5.2	---	---	---	41.0
1 North	08/19/1989	6.5	4.3	---	---	---	41.0
1 North	08/27/1989	5.8	3.4	---	---	---	26.4
1 North	09/04/1989	6.0	3.3	---	---	---	28.1
1 North	09/10/1989	5.5	4.1	---	---	---	33.2
1 North	09/16/1989	6.3	5.1	2.2	---	---	27.2
1 North	10/14/1989	5.5	4.1	---	---	---	30.7
1 North	11/19/1989	4.7	4.6	---	---	---	30.7

<< End of 1989 listing, 20 records >>

Pemaquid Lakes (Maine) Data on file as of 02/10/1990

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Paradise Pond, Maine
-- subset of trophic indicators, all sites, 1989

1989 SUMMARY

Average chlorophyll:	4.6	(1989:	15 values;	3.3	-	6.4	range)
Average phosphorus:	7.9	(1989:	3 values;	5.3	-	10.1	range)
Average color, 440:	73.2	(1989:	15 values;	50.4	-	90.8	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Reedls.	05/09/1989	---	---	5.3	---	---	---
1 Reedls.	05/21/1989	B.O.	3.9	---	---	---	85.6
1 Reedls.	05/29/1989	B.O.	5.1	---	---	---	90.8
1 Reedls.	06/04/1989	B.O.	3.4	---	---	---	90.8
1 Reedls.	06/18/1989	B.O.	3.6	---	---	---	83.1
1 Reedls.	06/25/1989	B.O.	6.4	---	---	---	80.5
1 Reedls.	07/02/1989	B.O.	6.1	---	---	---	78.8
1 Reedls.	07/09/1989	B.O.	4.5	---	---	---	73.6
1 Reedls.	07/16/1989	---	---	10.1	---	---	---
1 Reedls.	07/23/1989	B.O.	4.4	---	---	---	77.1
1 Reedls.	07/30/1989	B.O.	3.6	---	---	---	71.0
1 Reedls.	08/06/1989	B.O.	4.2	---	---	---	83.9
1 Reedls.	08/13/1989	B.O.	6.0	---	---	---	71.0
1 Reedls.	08/30/1989	B.O.	6.3	---	---	---	52.1
1 Reedls.	09/04/1989	B.O.	---	---	---	---	---
1 Reedls.	09/10/1989	B.O.	4.3	---	---	---	53.9
1 Reedls.	09/18/1989	B.O.	---	8.2	---	---	---
1 Reedls.	09/25/1989	B.O.	3.6	---	---	---	54.7
1 Reedls.	10/01/1989	B.O.	3.3	---	---	---	50.4

<< End of 1989 listing, 19 records >>

Pemaquid Lakes (Maine) Data on file as of 02/10/1990

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Boyd Pond, Maine
-- subset of trophic indicators, all sites, 1989

1989 SUMMARY

Average transparency:	3.8	(1989:	19	values;	3.3	-	4.5 range)
Average chlorophyll:	4.3	(1989:	19	values;	2.7	-	5.8 range)
Average phosphorus:	4.2	(1989:	3	values;	3.7	-	4.6 range)
Average color, 440:	47.8	(1989:	19	values;	32.4	-	61.6 range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Center	05/09/1989	---	---	3.7	---	---	---
1 Center	05/28/1989	3.6	4.0	---	---	---	60.7
1 Center	06/03/1989	4.2	3.4	---	---	---	54.7
1 Center	06/11/1989	3.6	4.3	---	---	---	57.3
1 Center	06/18/1989	4.0	2.7	---	---	---	61.6
1 Center	06/24/1989	3.7	3.9	---	---	---	55.6
1 Center	07/01/1989	3.7	5.5	---	---	---	55.6
1 Center	07/08/1989	3.7	5.2	---	---	---	58.2
1 Center	07/15/1989	3.3	5.8	4.4	---	---	51.3
1 Center	07/23/1989	3.5	5.3	---	---	---	56.4
1 Center	07/30/1989	3.8	3.6	---	---	---	43.6
1 Center	08/14/1989	4.0	4.8	---	---	---	42.7
1 Center	08/19/1989	4.2	4.3	---	---	---	36.7
1 Center	08/27/1989	4.4	3.6	---	---	---	39.3
1 Center	09/02/1989	4.1	3.6	---	---	---	35.0
1 Center	09/09/1989	4.5	3.6	---	---	---	34.1
1 Center	09/16/1989	4.4	4.3	4.6	---	---	32.4
1 Center	10/08/1989	3.5	4.8	---	---	---	36.7
1 Center	10/22/1989	3.3	4.6	---	---	---	39.3
1 Center	10/29/1989	3.6	4.5	---	---	---	56.4

<< End of 1989 listing, 20 records >>

METHODS OF LAY MONITORS

Lay monitors receive their initial training either on-site or on campus from a member of the **FBG**. Workshops covering new techniques are usually offered on a yearly basis and updates may be held on-site during an **FBG** sampling trip.

This year data were collected on five parameters: thermal stratification, water clarity (secchi disk depth), total phosphorus, chlorophyll a concentration and dissolved color. Whenever possible, testing was done weekly between the hours of 9 am and 3 pm, the period of maximum sunlight penetration into the water. All samples and data were mailed or hand delivered to the **FBG** at UNH for analysis.

Thermal (temperature) profiles were obtained by collecting lakewater samples at several successive depths using a modified Meyer bottle (Lind, 1979). A weighted, stoppered, empty bottle was lowered to a specific depth. At that depth, the stopper was pulled, allowing the bottle to be filled with water. The bottle was quickly pulled back up to the surface where the temperature of the sample was taken with a Taylor pocket thermometer, and recorded in degrees C. This procedure was repeated at one meter intervals through the epilimnion (upper water column), at one-half meter intervals throughout the metalimnion (depths at which the temperature change is greater than 1 degree C per meter) and at one meter intervals through the hypolimnion (depths below the metalimnion).

Water clarity was measured by lowering a secchi disk (approximately 20 cm. or 8 inches) through the water off the shaded side of the boat, and noting the average of the depths at which it disappeared upon lowering and reappeared when being raised (the cord attached to the secchi disk is marked in one tenth of a meter for the first half meter and in one-half meters thereafter). Water clarity was determined while holding a view-scope just below the surface to eliminate effects of surface reflection and wave action. This was repeated two or three times, and an average to the nearest one-tenth of a meter was recorded.

Chlorophyll a concentration was used as an index of algal biomass that is useful in determining the trophic state of the lake. A weighted plastic tube (10 meters in length) was lowered through the epilimnion to the top of the metalimnion (the depths of the epilimnion and metalinmion are determined from the temperature profile). The end of the tube above water is folded to shut off the water flow into or out of the tube. The weighted end of the tube is pulled up out of the water with an attached cord, trapping an integrated sample of water representing the "upper lake" in the tube. This sample is poured into a blue plastic 2.5 liter bottle and stored in the shade until chlorophyll filtration could be done.

Water samples for chlorophyll a filtration were filtered through a 0.45 micron membrane filter under low vacuum. Damp filters, containing chlorophyll-bearing algae, were air-dried for at least 15 minutes, in the dark, to prevent decomposition or bleaching of the chlorophyll on the filter. These filters were sent to UNH where members of the **FBG** analyzed them for chlorophyll a (see Methods of the Freshwater Biology Group).

Dissolved water color was determined by saving the filtrate from the the chlorophyll filtration and storing it frozen in a 50 ml plastic bottle. The bottles were sent to UNH and the color was analyzed by the **FBG** team (see Methods of the Freshwater Biology Group).

METHODS OF THE FRESHWATER BIOLOGY GROUP

Laboratory Methods

Chlorophyll samples were filtered through a 0.45 micron membrane filter and air-dried in the dark until analysis. The chlorophyll a content was analyzed by extracting the chlorophyll with a 95% acetone solution saturated with magnesium carbonate. The samples were then centrifuged and their light absorbance read at two standard wavelengths (663 and 750 nanometers) with a Milton Roy model 1001+ spectrophotometer equipped with 50mm cuvettes. An absorptivity value of 84 gm liter^{-1} cm^{-1} (Vollenweider 1969) was used for calculating the concentrations.

Dissolved color of the filtrate from chlorophyll filtrations was determined by reading the absorbance of the samples at two different wavelengths (440 and 493 nanometers) in a 50mm light path. The two readings were converted to the more widely used platinum cobalt color values with our standard curves of the absorbance of chloroplatinate.

Phosphorus samples were preserved with 1.0 milliliter of concentrated sulphuric acid and refrigerated until analysis. To determine the total phosphorus content, ammonium persulfate and 11 N sulphuric acid was added to digest the total phosphorus, and the samples were autoclaved for thirty minutes at 250 to 260 degrees C. Reagents included potassium antimony tartrate, ammonium molybdate, and a solution of ascorbic acid mixed fresh before each sample run (APHA 1985, EPA 1979). Absorbance of the blue phosphorus complex was measured with the spectrophotometer at 660 nanometers. A standard curve of the absorbance of a potassium phosphate (monobasic) solution was used to convert the readings to total phosphorus concentrations. Each sample was analyzed twice and an average of the two values was recorded as the phosphorus content in parts per billion (ppb).

Data Analysis

All field and laboratory data was filed and stored on the FBG computerized data management system that utilizes a mainframe DEC VAX-8650 computer and an IBM compatible micro-computer (Zenith Data Systems 158). With full use of relational data bases, such as S1032 and Dbase III+, data can be retrieved easily by date, station, or by parameter for within-lake comparison, or between-lake comparisons with other lake data bases (Lakes Lay Monitoring Program, New Hampshire Water Supply and Pollution Control, N.H. Fish and Game, EPA Surface Water Survey and others). Spreadsheet, statistics and graphics packages on both the mainframe and micro-computer enable data analysis and presentation.

Trophic boundaries of Forsberg and Ryding (1980) of transparency, chlorophyll a, and total phosphorus are used as criteria in discussions of the trophic state of the Pemaquid Lakes. Phytoplankton are reported both as species and classes. Crustacean zooplankton were identified to genus or species and classified into one of four categories depending on their size (large or small) and their feeding preferences (herbivore or predator) with a modified version of criteria from Sprules (1980). The differences in abundance between the different groups allow for a more complete description of the zooplankton community and the trophic classification of lakes.

APPENDIX C

GLOSSARY

Aerobe	Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.
Algae	See phytoplankton.
Alkalinity	Total concentration of bicarbonate and hydroxide ions (in most lakes).
Anaerobe	Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.
Anoxic	A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.
Benthic	Referring to the bottom sediments.
Bacterioplankton	Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.
Bicarbonate	The most important ion (chemical) involved in the buffering system of New Hampshire lakes.
Buffering	The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the main chemical responsible for buffering is the bicarbonate ion. (See pH.)
Chloride	One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.
Chlorophyll a	The main green pigment in plants. The concentration of chlorophyll a in lakewater is often used as an indicator of algal abundance.
Circulation	The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.
Density	The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

Dimictic	The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).
Dystrophy	The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll a concentration may be low or high.
Epilimnion	The uppermost layer of water during periods of thermal stratification. (See lake diagram).
Eutrophy	The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi disk depth, high chlorophyll a, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.
Free CO2	Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.
Holomixis	The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)
Humic Acids	Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.
Hydrogen Ion	The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.
Hypolimnion	The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)
Lake	Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.
Lake Morphology	The shape and size of a lake and its basin.
Meromixis	The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll a, Secchi disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

Metalimnion The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree Celsius per meter depth. Also called the thermocline.

Mixis Periods of lakewater mixing or circulation.

Mixotrophy The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll a values are also high.

Oligotrophy The lake trophic state where algal production is low, Secchi disk depth is deep, and chlorophyll a and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn See circulation or mixis

pH A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10^{-5} molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14.

Photosynthesis The process by which plants convert the inorganic substance carbon dioxide into organic glucose (sugar) using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion — Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

Plankton — Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

Saturated — When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

Specific Conductivity — A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum — A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification — The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind. (See Appendix B.)

Thermocline — Region of temperature change. (See metalimnion.)

Total Phosphorus — A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic Status — A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories, and Appendix B)

Z — A symbol used by limnologists as an abbreviation for depth.

Zooplankton — Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: <u>Daphnia</u>, <u>Cyclops</u>, <u>Bosmina</u>, and <u>Kellicottia</u>.